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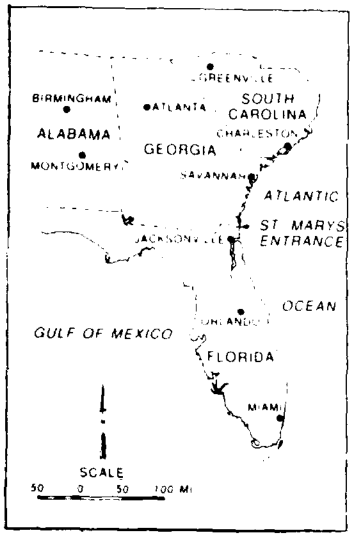
US Army Corps of Engineers

CUMBERLAND SOUND MONITORING

Report 3
1990 DATA COLLECTION REPORT



by

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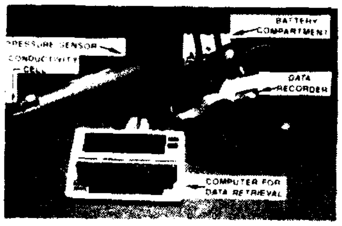

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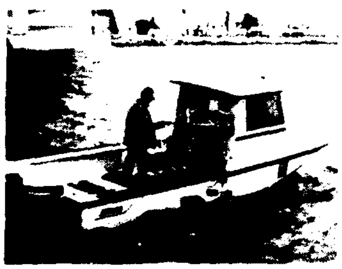

April 1992

Report 3 of a Series

HYDRAULICS LABORATORY

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Water level, conductivity, temperature, and salinity were measured in the Cumberland Sound study area during January 1990 through December 1990. The data were collected as part of a long-term study to assess, through comparisons with earlier data collection programs, if changes to the estuarine processes of the study area have occurred. This report describes the equipment and procedures used in the data collection effort and presents tables and plots of representative data.

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PREFACE

The work described in this report was performed by the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES) during January 1990 through December 1990 as a part of the overall Cumberland Sound Monitoring Program conducted for the Department of the Navy under the coordination of the US Army Engineer Division, South Atlantic (SAD).

This study was conducted under the direction of Messrs. Frank A. Herrmann, Jr., Chief, HL; Richard A. Sager, Assistant Chief, HL; William H. McAnally, Jr., Chief, Estuaries Division; George M. Fisackerly, Chief, Estuarine Processes Branch; and Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch, Coastal Engineering Research Center (CERC). Technical direction and guidance during the study were provided by Messrs. Albert G. Green, Jr., National Park Service (NPS), Thomas J. Peeling, Naval Facilities Engineering Command (NAVFACENGCOM), John Headland, NAVFACENGCOM, Darryl Molzan, NAVFACENGCOM, the late William Odum, University of Virginia, Charlottesville, VA, and Robert G. Dean, University of Florida, Gainesville, FL, as members of the Kings Bay Coastal and Estuarine Monitoring Program Technical Review Committee.

This report was prepared by Messrs. Fisackerly, Timothy L. Fagerburg, and Joseph W. Parman and Mrs. Clara J. Coleman all of EPB. The HL portion of the project study was managed by Mr. Fisackerly. The field data collection program was designed by Messrs. Fisackerly, Allen M. Teeter, Howard A. Benson, and Mitchell A. Granat, and executed under the direction of Messrs. Fisackerly, Fagerburg, and Benson. Other WES personnel participating in the data collection effort were Messrs. Samuel E. Varnell, Thad C. Pratt, and Larry G. Caviness.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassell, EN.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet per second	0.02831685	cubic metres per second
degrees Fahrenheit	5/9*	Celsius degrees or kelvins
feet	0.3048	metres
inches	2.540	centimetres
miles (US nautical)	1.852	kilometres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F-32)$. To obtain kelvin (K) readings, use: $K = (5/9)(F-32) + 273.15$.

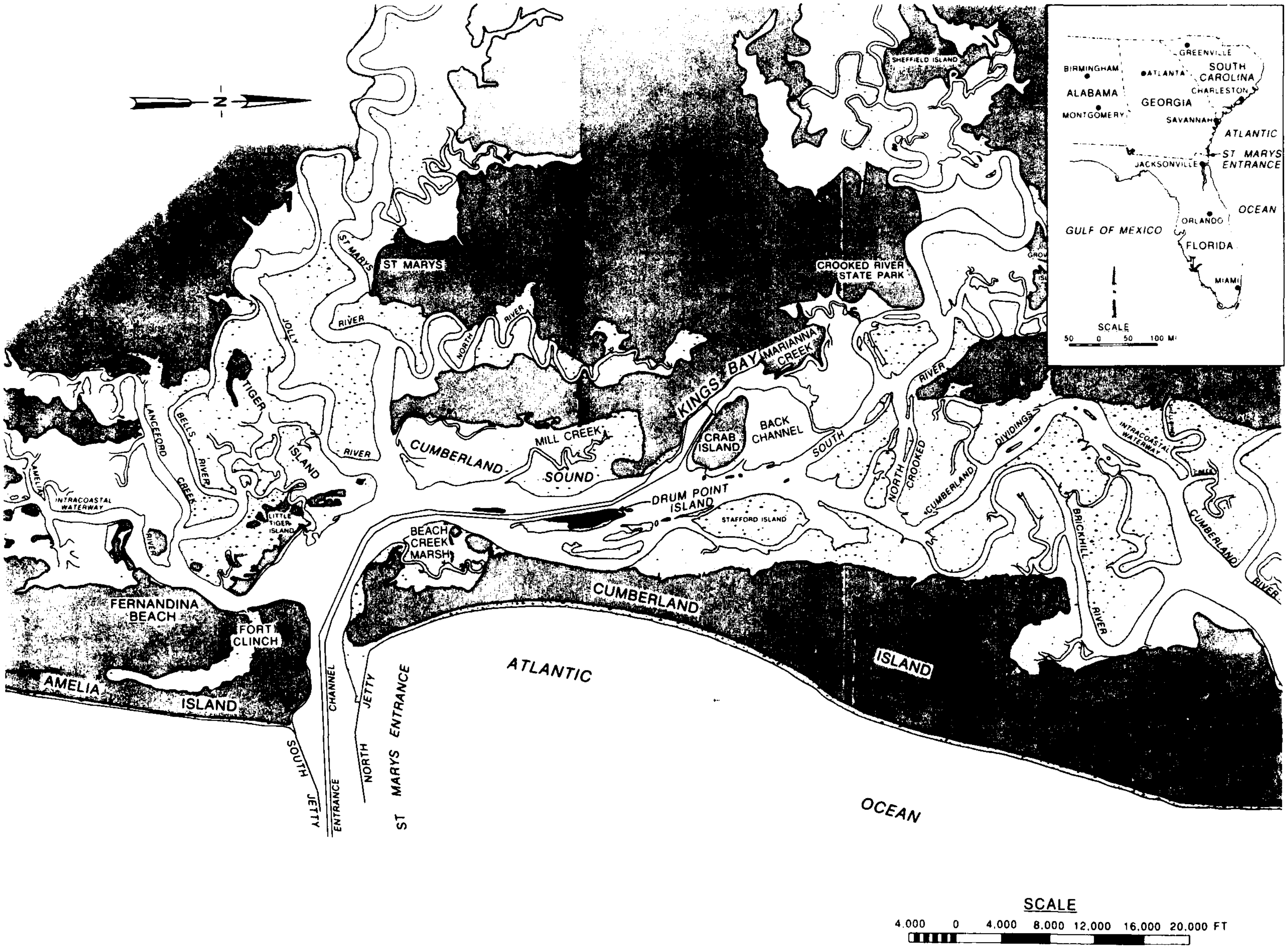

Figure 1. Cumberland Sound and Kings Bay vicinity map

CUMBERLAND SOUND MONITORING

1990 DATA COLLECTION REPORT

PART I: INTRODUCTION

Background

1. The Cumberland Sound estuarine system in southeast Georgia includes extensive salt marshes and sand flats (shaded areas in Figure 1) typical of the sea island system of southeast Georgia. A Naval Submarine Base, Kings Bay, is located within the sound about 9.6 nautical miles (n.m.)* north of the St. Marys Inlet entrance jetties at the Atlantic Ocean. The mean tidal range at the ocean entrance between Amelia Island, in the state of Florida, and Cumberland Island, in the state of Georgia, is 5.8 ft. Maximum spring tidal ranges can exceed 8.0 ft in the interior portions of the estuary.

2. The primary sources of fresh water for the Cumberland Sound estuarine system are the St. Marys and the Crooked Rivers. The long-term average freshwater discharge at the mouths of the rivers is about 1,500 cfs from the St. Marys River and 100 cfs from the Crooked River. Suspended sediment loads within the rivers are generally low.

3. Cumberland Sound is considered to be a well-mixed estuarine system due to the relatively low average total freshwater discharge and the relatively high tidal range and associated strong current velocities. Salinity within the sound and Kings Bay is generally vertically and laterally homogeneous. Longitudinally, salinity within the sound is only slightly reduced from the ocean entrance conditions. Salinity in Kings Bay typically varies from about 26 to 32 ppt during the year.

4. The original Kings Bay facility was designed and developed as an emergency Army Munitions Operation Transportation facility in the late 1950's. Initial navigation channel depths in the sound leading to Kings Bay were authorized at 32 ft mean low water.** The facility was never placed into

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* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

** All depths and elevations (el) described in this report refer to local mean low water (mlw), which is 2.75 ft below National Geodetic Vertical Datum (NGVD).

operational use but was in a standby mobilization status and channel depths of about 32 ft were maintained. Figure 1 shows the general Cumberland Sound and Kings Bay area.

5. The Department of the Navy acquired the Kings Bay facility in July 1978 for use as a submarine base for Poseidon-class submarines. Between July 1978 and July 1979, major channel realignment, widening, and deepening were performed for Poseidon facility expansion on the lower entrance channels and the interior approach channels. The total length of the interior Poseidon channel, from the throat of St. Marys entrance adjacent to Fort Clinch to the end of the main docking facility, was about 7 n.m.

6. In the 1980's with the advent of the Trident submarines, changes to the channel were made to accommodate these large submarines. The Trident facilities expansion included widening and deepening the approach channel, deepening the ocean entrance, deepening and widening portions of Kings Bay, as well as construction of various facilities in and around the submarine base. The specifics of these changes have been described in earlier reports.*,**

7. These recent changes raised concerns by the State of Florida and the Department of Interior (DOI) about the potential for adverse impacts to coastal processes on Amelia Island to the south and on the Cumberland Island National Seashore to the north of St. Marys Inlet.

8. As a result of these concerns, a 5-year study (1988-1992) was established to assess the effects of the Trident project on the estuarine and coastal processes in the area of Cumberland and Amelia Islands and Cumberland Sound. The US Army Engineer Waterways Experiment Station (WES) Hydraulics Laboratory is responsible for the program's estuarine studies. These studies include some numerical model testing and long- and short-term field data collection to assess the potential effects on the hydrodynamics of the system. The areas of interest included tidal effects, changes in salinity, and sedimentation. The WES Coastal Engineering Research Center (CERC) is responsible

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* Mitchell A. Granat, Noble J. Brogdon, John T. Cartwright, and William H. McAnally, Jr. 1989. "Verification of the Hydrodynamic and Sediment Transport Hybrid Modeling System for Cumberland Sound and Kings Bay Navigation Channel, Georgia," Technical Report HL-89-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

** Timothy L. Fagerburg, Howard A. Benson, Joseph W. Parman, and George M. Fisackerly. 1991. "Cumberland Sound Monitoring, Report 1, 1988 Data Collection," Technical Report HL-91-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

for the coastal portions of the program and is the central point of contact for the entire Kings Bay monitoring effort of WES.

9. The US Army Engineer Division, South Atlantic, serves as the lead office for coordination between the US Army Corps of Engineers and the Navy. In addition to WES, other organizations involved in the overall monitoring program are the US Navy, US Army Engineer Division, South Atlantic, DOI, National Park Service, and the US Army Engineer Districts of Savannah and Jacksonville.

Purpose

10. The purpose of the overall Cumberland Sound monitoring program is to provide long-term monitoring of tides and conductivity and temperature measurements at six stations throughout the sound estuarine system over a 5-year project duration. The purpose of this report is to present representative samples of the long-term data that were collected during the third year of the project.

Scope

11. This report presents representative results of the field data collection program in the Cumberland Sound system during calendar year 1990. Measurements consisted of the following at each of the six stations:

- a. Water-level elevations.
- b. Conductivity and temperature measurements for salinity calculations.
- c. Composite water samples for laboratory measurement of salinity and suspended sediment concentrations.

12. The field investigation methods used to collect the data are described, representative data are shown, and the source of supply for obtaining the complete data for further use is given.

PART II: EQUIPMENT, PROCEDURES, AND CONDITIONS IN THE FIELD AND SAMPLE ANALYSIS IN THE LABORATORY

Equipment

13. Water level elevations and temperature, conductivity, and salinity measurements were recorded using Environmental Devices Corporation (ENDECO) model 1152 SSM (solid state measurement) water level recorders similar to the recorder shown in Figure 2. Water samples for determining suspended sediment concentrations were obtained using American Sigma Streamline Model 702 automatic water samplers similar to the sampler shown in Figure 3.

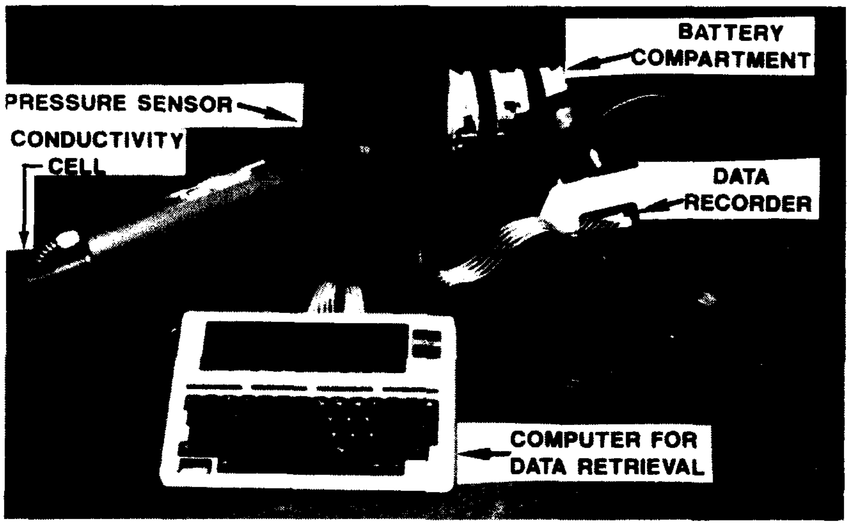


Figure 2. Water level recorder

Water level recorder

14. The ENDECO model 1152 SSM recorder contains a strain-gage-type pressure transducer located in a subsurface case which is used to record the absolute pressure of the column of water above the case. The pressure transducer is vented to the atmosphere by a small tube in the signal cable to compensate for any changes in atmospheric pressure. Pressure was measured for 49 sec of each minute of the recording interval with a frequency of 5-55 kHz to filter out surface waves, thereby eliminating the need for a stilling well. Accuracy was ±0.02 ft. The sampling time interval can be set from 1 min to 1 hr on the 1152 SSM. A 10-min sampling interval was chosen for this study.

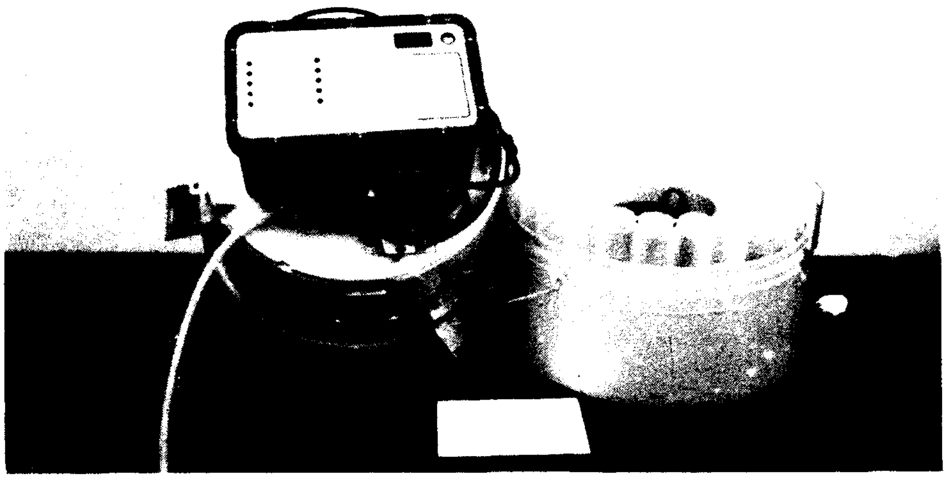


Figure 3. Automatic water sampler

Temperature, conductivity,
and salinity measuring equipment

15. Temperature was measured by means of a thermistor built into the water level recorder. The thermistor has a range of −5 C to +45 C, with an accuracy of ±0.08 C. Conductivity was measured by means of an inductively coupled probe. The probe has a range of 0–80 mmho/cm with an accuracy of ±0.55 mmho/cm. Salinity values are then computed from the output of the conductivity and temperature measurements and displayed in units of parts per thousand (ppt).

16. The sampling time interval for these parameters was set for 10 min, the same as that for the water level measurements; the time intervals cannot be set independently. The data from each recorder were stored on a removable EPROM solid state memory cartridge located in a waterproof interface unit which also contained the DC power supply.

Automatic water sampler

17. Composite water samples (multiple samples per sample bottle) were obtained at each water level recorder location using American Sigma Streamline water sampler model 702, as shown in Figure 3. A typical field installation of these water samplers is shown in Figure 4. The samplers operate from a 12-volt d-c battery. Samples are collected in 1-ℓ plastic bottles inside the sampler housing. The samplers are fully programmable for (a) obtaining any volume of sample desired up to the maximum size of the bottle, (b) obtaining composite samples, and (c) setting times to begin the sampling routine. Upon

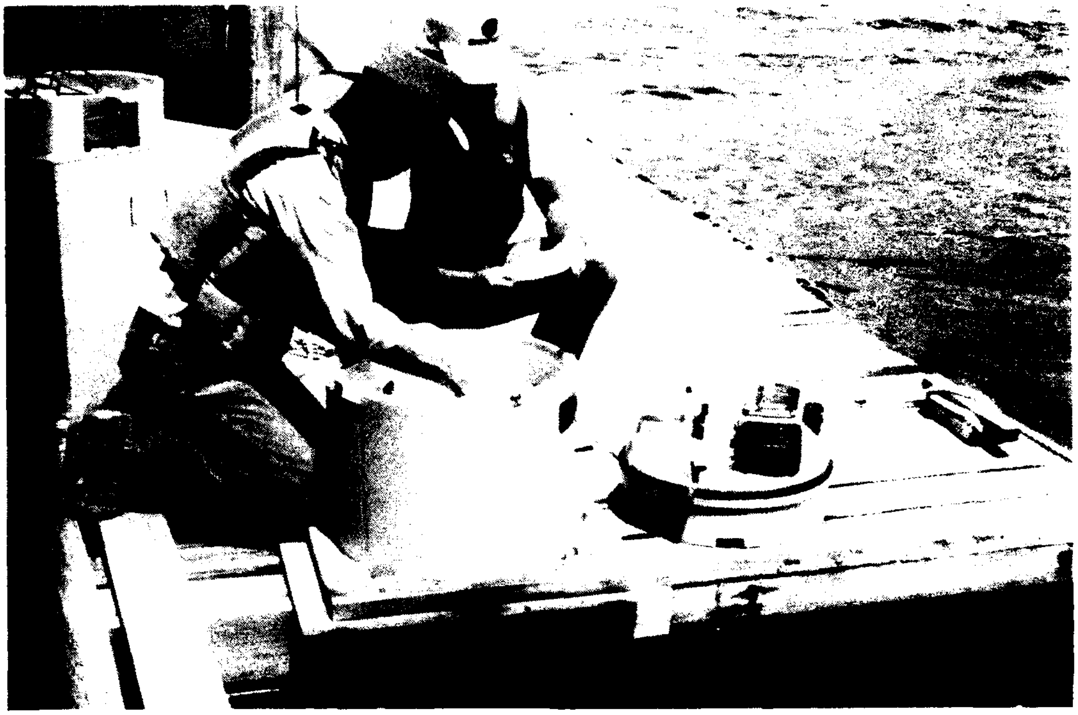


Figure 4. Field installation of water sampler

completion of the sampling program, the bottles are removed and replaced with empty ones to begin the new sampling period.

18. Six samplers, one at each water level recorder location, were installed in July 1989. The intake lines to the samplers were set to obtain samples at approximately the middepth of each location. The samplers were programmed to collect four samples per bottle with the time interval between samples set for 373 min.

Measurement locations

19. Six water level recorders and six water samplers were deployed throughout the Cumberland Sound system as shown in Figure 5. The locations selected adequately covered the total study area to provide information on (a) differences in time of peak tides and range of tides and (b) salinities and sediment concentrations.

Field Service Procedures

20. Periodic equipment service trips (usually monthly) were made by WES personnel. Servicing included first making a visual inspection of the equipment. The sample bottles from each sampler were removed and replaced with

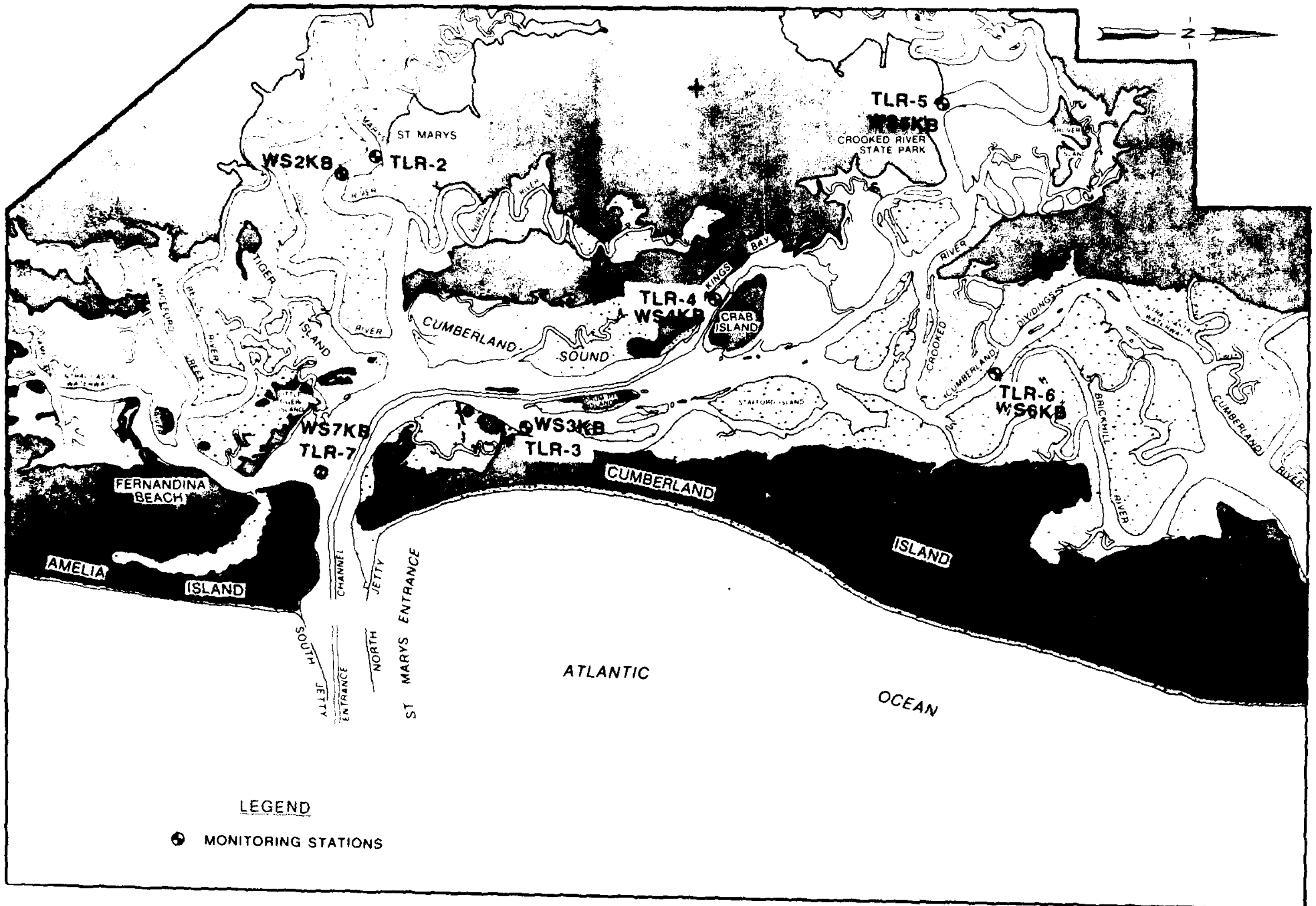


Figure 5. Location of Cumberland Sound monitoring stations

empty ones. Intake lines were inspected and cleaned of any aquatic growth or obstruction. Batteries were replaced and the samplers were reprogrammed to begin a new sampling period.

21. A portable computer was connected to the 1152 SSM water level recorder to obtain a current display of the data that the sensor was obtaining. These data were compared with in-field checks of salinity and water level. In-field checks of salinity were made using a portable Aanderaa salinity meter, as shown in Figure 6. A water sample was also collected at the same depth as that of the sensor and returned to the laboratory along with the other water samples for analysis of salinity and sediment concentrations.

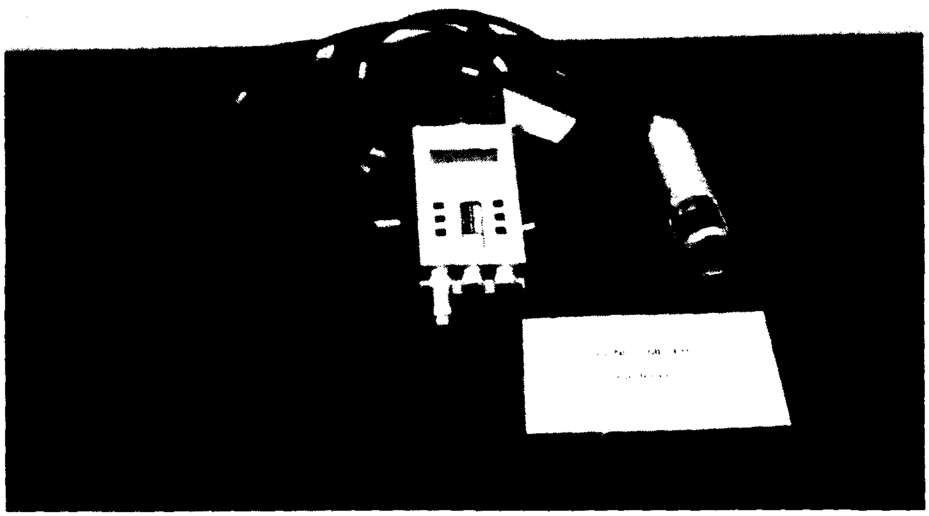


Figure 6. Portable salinity meter

22. The approximate water depth over the sensor was also recorded by measuring the distance from the water surface to a known reference point on the sensor support bracket. The data recording cartridge was then removed and replaced with a new cartridge. New batteries were installed and the desiccant, used to absorb moisture in the surface housing, was replaced.

23. The subsurface sensor was brought to the surface and inspected, and any barnacles or other aquatic growth were removed. The cleaned sensor was returned to its original position, and the computer was connected to the 1152 SSM. The instrument's readings were then compared with a new set of in-field measurements. This procedure was performed on all the recording

units to ensure that they were operating properly.

Meteorological Conditions

24. The Cumberland Sound/Kings Bay area has an annual mean temperature of 70 F with extremes ranging from the teens to 100 F. The yearly average rainfall is 50-55 in. Freshwater inflows from the St. Marys River are determined from river stages recorded at a US Geological Survey (USGS) gaging station near Macclenny, FL. These data, gage height and discharges for the water year October 1989 to September 1990, are presented in Tables 1 and 2.

Laboratory Analysis of Water Samples

25. The samples collected by the water samplers were analyzed at WES. Total suspended materials were determined by filtration of the samples. Nuclepore polycarbonate filters of 0.4-μ pore size were used in this procedure. The samples were desiccated and preweighed, and a vacuum system was used to draw the sample through the filter. The filters and holders were washed with distilled water, dried at 105 C for 1 hr, and reweighed. The total suspended materials were calculated based on the weight and volume of the filtered sample.

26. The laboratory analyses of the salinities for the water samples were performed using an AGE Instruments Incorporated Model 2100 MINISAL salinometer. This microprocessor-controlled instrument calculates and displays salinity with calibrations for temperature, cell constant, and salinity of standard seawater. Standard seawater was used as the standard during all analyses. The accuracy of the measurements was ±0.003 ppt on samples ranging from 2 to 42 ppt. The samples were analyzed and recorded to the nearest 0.01 ppt.

PART III: THE DATA

27. The data collected in the monitoring program described herein are recorded in both tabular and graphical format. Because of the enormous amounts of data collected only representative samples are presented in this report. For more detailed information, the reader may obtain the tabulated computer printouts and graphic plots upon written request to the following address.

USACE Waterways Experiment Station
ATTN: CEWES-HE-P
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

This same information is also available on computer diskettes.

28. Tables 3 and 4 are examples of the tabulated format for the water levels (depth of sensor below water surface), salinities, and temperatures that are available for each data recording location. Time is given in hours and minutes, Eastern Standard Time (EST), for each reading of depth, conductivity, temperature, and salinity.

29. Tables 5-7 are examples of the format for the suspended sediment concentrations that are also available for each data recording location.

30. As with any long-term measurement effort, there are periods when the equipment malfunctions for various reasons. Tables 8 and 9 list the status of each water level-salinity-temperature recorder and water sampler during the 12-month data collection period (1-1-90 through 12-31-90).

31. Typical examples of the graphical format for the water levels, salinities, temperatures, and suspended sediment concentrations are presented in Plates 1-36. These plots illustrate the changes that typically occur during various seasons of the year. Plates 1-9 display the water levels, salinities, and temperatures during the spring period (March-April). Plates 10-18 display the data collected during the summer period (July). Plates 19-24 display the data collected during the autumn period (October). Plates 25-33 display the data collected during the winter period (November-December). Suspended sediment concentrations for the corresponding spring, summer, and autumn periods are displayed in Plates 34-42.

32. The locations used for the representative samples were chosen to show the changing conditions with the seasons in the St. Marys entrance area

(TLR-7 and WS7KB; high salinity), in the Navy submarine base (TLR-4 and WS4KB; limited freshwater inflow), and in the Crooked River area (TLR-5 and WS5KB; small watershed freshwater inflow).

33. Datum planes for the tide data at each location are correctable to mean low water (mlw) from tidal benchmarks that were established in August 1989. The datum for each water level elevation plot represents the mean water level reading for each location. The mlw correction for each plot is noted on the plates.

PART IV: SUMMARY

34. The information presented herein represents a portion of the data collected during the third year of the Cumberland Sound monitoring. This report is the third in a series of four annual interim data reports. All information from each period of the study will be used to determine if changes to the estuarine processes have occurred due to physical changes of the navigation channel. This determination will be made through comparisons of the data from this 5-year study with data collected prior to the changed channel conditions.

Table 1

Mean Values of Gage Height for St. Marys River Near Macclenny, FL

October 1989 - September 1990

GAGE HEIGHT, FEET, WATER YEAR OCTOBER 1989 TO SEPTEMBER 1990
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	11.12	2.39	1.54	4.33	3.84	7.14	6.14	2.27	1.10	.99	.84	.93
2	11.14	2.31	---	5.18	3.88	6.59	6.37	2.04	1.07	.95	.82	.99
3	10.96	2.22	---	5.37	3.70	6.14	5.92	1.87	1.22	.94	.80	.90
4	10.31	2.14	---	5.08	3.54	5.78	5.70	1.74	1.30	.94	.79	.88
5	9.37	2.07	1.43	4.77	3.43	5.46	5.34	1.64	1.25	.92	.77	.87
6	8.45	2.00	1.42	4.53	3.47	5.12	4.90	1.56	1.27	.90	.75	.86
7	7.45	1.94	1.41	4.40	3.36	4.82	---	1.50	1.25	.89	.77	.84
8	6.50	1.89	1.43	4.58	3.20	4.56	---	1.45	1.62	.88	.90	.82
9	5.76	1.93	1.60	5.31	3.08	4.33	---	1.40	3.18	.85	1.09	.81
10	5.20	2.07	1.99	5.38	3.00	4.12	---	1.37	3.54	.84	1.09	.82
11	4.78	2.13	2.10	5.05	3.97	3.92	---	1.33	2.74	.83	1.02	.85
12	4.45	2.02	2.00	4.73	5.58	3.72	---	1.29	2.23	.84	1.14	.85
13	4.17	1.93	2.00	4.44	5.85	3.52	---	1.26	1.89	.88	1.30	.81
14	3.92	1.88	2.22	4.17	5.35	3.34	---	1.22	1.65	1.01	1.16	.78
15	3.69	---	2.26	3.94	4.85	3.18	---	1.20	1.48	1.20	1.06	.77
16	3.49	---	2.15	3.77	4.47	3.04	2.59	1.17	1.37	1.41	1.26	.77
17	3.34	---	2.07	3.62	4.21	2.92	2.46	1.13	1.33	1.33	1.14	.78
18	3.39	---	2.10	3.49	4.08	2.96	2.33	1.11	1.31	1.15	1.05	.81
19	4.04	---	2.60	3.36	4.09	3.08	2.22	1.10	1.23	1.11	1.04	.77
20	4.59	1.64	4.69	3.25	5.86	2.98	2.13	1.07	1.17	1.21	1.00	.73
21	4.61	1.62	6.05	3.14	8.77	2.83	2.06	1.05	1.12	1.23	.96	.71
22	4.53	---	6.08	3.16	9.58	2.69	2.01	1.08	1.08	1.36	.93	.70
23	4.32	---	5.68	3.64	9.88	2.57	2.00	1.06	1.07	1.26	.95	.69
24	3.97	---	5.43	3.77	10.25	2.47	2.07	1.04	---	1.19	1.03	.68
25	3.62	---	5.26	3.57	10.07	2.37	2.13	1.03	---	1.24	.95	.67
26	3.33	---	5.08	3.54	9.42	2.28	2.06	1.02	1.05	1.16	.90	.67
27	3.10	1.67	4.95	3.75	8.62	2.20	1.93	1.03	---	1.04	.86	.67
28	2.91	---	4.80	3.70	7.82	2.12	1.87	1.28	1.30	.99	.86	.68
29	2.75	---	4.61	3.49	---	2.06	2.15	1.39	1.15	.95	.84	.70
30	2.60	---	4.40	3.34	---	2.05	2.41	1.26	1.05	.91	.84	.76
31	2.48	---	4.20	3.43	---	3.38	---	1.15	---	.87	.86	---
MEAN	5.30	---	---	4.11	5.61	3.67	---	1.33	---	1.04	.96	.79
MAX	11.14	---	---	5.38	10.25	7.14	---	2.27	---	1.41	1.30	.99
MIN	2.48	---	---	3.14	3.00	2.05	---	1.02	---	.83	.75	.67

Note: From provisional tables in the USGS Annual Gage Height and Discharge Report for Water Year 1989.

Table 2

Mean Values of Discharge for St. Marys River Near Macclenny, FL

October 1989 - September 1990

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1989 TO SEPTEMBER 1990
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1860	144	e60	416	333	973	760	132	37	31	24	28
2	1870	136	e60	563	339	851	804	111	36	29	23	31
3	1810	127	e59	603	311	757	714	95	45	29	22	27
4	1620	120	e59	549	286	686	670	83	50	29	21	26
5	1470	113	59	493	270	622	599	75	47	28	21	25
6	1300	107	58	451	276	557	517	69	49	27	20	25
7	1050	102	58	429	260	501	e420	64	47	26	20	24
8	333	97	59	461	237	456	e360	60	74	26	27	23
9	682	101	72	594	220	416	e310	57	247	24	37	23
10	572	113	106	606	210	380	e280	55	287	24	37	23
11	495	119	116	544	360	345	e240	52	181	23	33	24
12	437	109	107	486	646	313	e220	50	128	24	40	24
13	389	100	107	435	700	283	e200	47	96	26	50	22
14	346	96	128	388	601	257	e180	45	76	33	41	21
15	303	e92	131	349	508	234	e165	44	63	44	35	21
16	279	e88	121	321	441	215	165	42	55	57	48	21
17	256	e85	113	298	394	201	151	40	52	52	40	21
18	265	e82	116	278	373	206	133	38	51	41	35	22
19	366	e78	168	260	374	221	127	38	46	38	34	21
20	462	75	482	243	712	208	119	36	42	44	32	19
21	465	74	739	229	1410	190	113	35	39	46	30	18
22	450	e72	747	232	1640	176	108	37	36	54	28	18
23	415	e70	665	301	1740	153	107	36	e36	48	30	17
24	354	e68	615	322	1870	152	114	34	e43	43	34	17
25	298	e67	583	290	1810	142	119	34	e44	46	30	15
26	255	e66	550	286	1600	133	112	33	e46	42	27	16
27	223	e64	525	319	1360	125	101	34	e48	34	25	16
28	200	e63	499	310	1150	118	95	49	50	31	25	16
29	181	e62	465	278	---	113	121	57	41	30	24	13
30	166	e61	429	257	---	111	146	48	35	27	24	20
31	153	---	393	270	---	232	---	41	---	25	25	---
TOTAL	19830	2751	8449	11866	20431	10337	8275	1671	2127	1081	942	643
MEAN	640	91.7	273	383	730	335	276	53.9	70.9	34.9	30.4	21.4
MAX	1870	144	747	606	1870	973	304	132	287	57	50	31
MIN	153	61	58	229	210	111	95	33	35	23	20	16
CFSM	.91	.13	.39	.55	1.04	.48	.39	.08	.10	.05	.04	.03
IN.	1.05	.15	.45	.63	1.09	.55	.44	.09	.11	.06	.05	.03

e Estimated

Note: From provisional tables in the USGS Annual Gage Height and Discharge Report for Water Year 1989.

Table 3

Sample Printout of Water Level Recorder Data for Station TLR-2

KINGS BAY - STA T2 ST. MARYS NPS DOCK - 9 MARCH - 4 APRIL 1990

ENDECO TYPE 1152 DENSITY COMPENSATING WATER LEVEL RECORDER PAGE:
DATUM OFFSET APPLIED: -2.520 (FEET)
SERIAL NUMBER: 11520280

DATE (MM/DD/YY)	TIME (HH:MM)	TEMPERATURE (CELSIUS)	CONDUCTIVITY (MMHO/CM)	SALINITY (PPT)	DEPTH (FEET)
03/09/90	11:00	16.75	22.87	16.7	4.087
03/09/90	11:10	16.71	23.04	16.9	3.792
03/09/90	11:20	16.72	22.63	16.5	3.527
03/09/90	11:30	16.79	22.35	16.3	3.261
03/09/90	11:40	16.89	21.45	15.5	3.036
03/09/90	11:50	16.91	20.74	15.0	2.783
03/09/90	12:00	17.10	20.74	14.9	2.535
03/09/90	12:10	17.10	20.59	14.8	2.285
03/09/90	12:20	17.12	19.68	14.1	2.055
03/09/90	12:30	17.10	19.26	13.7	1.820
03/09/90	12:40	17.13	19.15	13.6	1.647
03/09/90	12:50	17.12	18.77	13.3	1.484
03/09/90	13:00	17.16	18.57	13.2	1.333
03/09/90	13:10	17.17	18.13	12.8	1.159
03/09/90	13:20	17.17	17.66	12.5	1.048
03/09/90	13:30	17.19	17.35	12.2	.934
03/09/90	13:40	17.21	17.25	12.2	.849
03/09/90	13:50	17.24	17.27	12.2	.807
03/09/90	14:00	17.25	17.30	12.2	.800
03/09/90	14:10	17.11	16.92	11.9	.822
03/09/90	14:20	17.02	16.65	11.7	.887
03/09/90	14:30	17.00	16.54	11.7	1.022
03/09/90	14:40	16.99	16.18	11.4	1.173
03/09/90	14:50	16.98	15.88	11.2	1.313
03/09/90	15:00	17.01	15.78	11.1	1.529
03/09/90	15:10	17.03	15.43	10.8	1.724
03/09/90	15:20	17.02	15.31	10.7	1.918
03/09/90	15:30	17.04	15.27	10.7	2.162
03/09/90	15:40	17.05	15.26	10.7	2.403
03/09/90	15:50	17.05	15.26	10.7	2.651
03/09/90	16:00	17.06	15.29	10.7	2.883

Table 4

Sample Printout of Water Level Recorder Data for Station TLR-7

KINGS BAY - STA T7 ENTRANCE MARKER - 9 MARCH - 4 APRIL 1990

ENDECO TYPE 1152 DENSITY COMPENSATING WATER LEVEL RECORDER PAGE:
DATUM OFFSET APPLIED: -4.410 (FEET)
SERIAL NUMBER: 11520275

DATE (MM/DD/YY)	TIME (HH:MM)	TEMPERATURE (CELSIUS)	CONDUCTIVITY (MMHO/CM)	SALINITY (PPT)	DEPTH (FEET)
03/09/90	11:00	16.19	31.20	23.8	2.895
03/09/90	11:10	16.28	30.77	23.4	2.640
03/09/90	11:20	16.31	30.73	23.4	2.404
03/09/90	11:30	16.33	30.71	23.3	2.173
03/09/90	11:40	16.35	30.58	23.2	1.913
03/09/90	11:50	16.40	30.47	23.1	1.677
03/09/90	12:00	16.43	30.31	23.0	1.455
03/09/90	12:10	16.47	30.05	22.7	1.289
03/09/90	12:20	16.47	30.15	22.8	1.137
03/09/90	12:30	16.51	30.07	22.7	1.001
03/09/90	12:40	16.62	29.55	22.2	.882
03/09/90	12:50	16.63	29.29	22.0	.783
03/09/90	13:00	16.66	29.06	21.8	.717
03/09/90	13:10	16.77	28.82	21.5	.680
03/09/90	13:20	16.75	28.42	21.2	.676
03/09/90	13:30	16.77	28.47	21.2	.698
03/09/90	13:40	16.74	28.24	21.1	.748
03/09/90	13:50	16.84	28.10	20.9	.822
03/09/90	14:00	16.88	28.15	20.9	.960
03/09/90	14:10	16.75	28.50	21.3	1.087
03/09/90	14:20	16.73	29.11	21.8	1.194
03/09/90	14:30	16.73	29.95	22.5	1.322
03/09/90	14:40	16.68	28.78	21.5	1.499
03/09/90	14:50	16.69	29.62	22.2	1.620
03/09/90	15:00	16.72	29.96	22.5	1.800
03/09/90	15:10	16.67	29.94	22.5	2.007
03/09/90	15:20	16.65	30.20	22.7	2.220
03/09/90	15:30	16.62	30.26	22.8	2.449
03/09/90	15:40	16.56	30.33	22.9	2.683
03/09/90	15:50	16.59	30.46	23.0	2.932
03/09/90	16:00	16.51	30.58	23.1	3.169

Table 5

Daily Average of Suspended Sediment Concentrations

for the Automatic Water Samplers, mg/l

March 1990

Date Mar 90	Station No. WS2KB	WS3KB	WS4KB	WS5KB	WS6KB	WS7KB
8	62	74	23	31	47	178
9	69	40	24	33	58	104
10	30	29	24	28	84	79
11	31	21	45	26	93	87
12	55	17	24	20	14	58
13	38	22	21	31	18	119
14	68	36	23	24	14	116
15	59	36	24	24	26	151
16	40	24	23	22	10	161
17	45	11	47	14	26	142
18	41	24	18	16	22	96
19	66	13	65	15	24	91
20	54	11	51	20	49	85
21	43	22	88	14	34	87
22	38	42	18	13	35	169
23	18	56	29	12	31	132
24	22	58	15	16	21	99
25	37	71	14	27	17	53
26	34	64	19	23	23	151
27	36	96	11	18	35	111
28	36	87	26	24	30	83
29	37	59	15	27	47	90
30	19	42	14	31	118	163
31	35	32	14	25	108	114

Table 6

Daily Average of Suspended Sediment Concentrations

for the Automatic Water Samplers, mg/l

June/July 1990

Date Jun/Jul 90	Station No. WS2KB	WS3KB	WS4KB	WS5KB	WS6KB	WS7KB
14	47	*	20	40	39	19
15	167	*	22	34	90	8
16	46	*	23	18	93	15
17	57	*	18	13	66	18
18	48	*	16	48	63	19
19	39	*	15	46	59	2
20	39	*	20	47	103	32
21	50	*	27	39	73	37
22	36	*	23	62	221	27
23	51	*	21	56	31	23
24	56	*	20	49	28	29
25	44	*	24	41	66	33
26	56	*	23	37	18	42
27	51	*	23	34	17	62
28	53	*	18	38	38	45
29	44	*	13	32	52	61
30	23	*	16	33	40	46
1	20	*	14	21	63	47
2	35	*	12	18	48	40
3	33	*	12	24	40	45
4	33	*	20	24	58	58
5	55	*	11	21	57	53
6	83	*	13	*	*	56
7	57	*	10	34	*	77

* No sample due to equipment malfunction.

Table 7

Daily Average of Suspended Sediment Concentrations

for the Automatic Water Samplers, mg/l

September/October 1990

Date	Station No.					
Sep/Oct 90	WS2KB	WS3KB	WS4KB	WS5KB	WS6KB	WS7KB
27	16	17	6	15	18	284
28	17	17	9	16	16	69
29	20	24	9	21	32	76
30	24	26	11	23	49	82
1	30	31	11	32	54	93
2	34	47	6	36	61	89
3	46	69	3	34	76	109
4	41	44	8	17	79	109
5	*	49	16	36	97	110
6	*	49	11	46	103	98
7	*	38	12	57	93	85
8	*	58	14	52	81	67
9	*	44	18	56	81	80
10	*	48	26	84	59	100
11	*	64	21	69	62	109
12	*	53	26	70	73	101
13	*	71	21	70	72	78
14	*	58	15	62	65	67
15	*	66	19	53	76	59
16	*	49	24	55	73	59
17	*	76	18	71	42	61
18	*	53	21	56	59	48
19	*	44	15	55	62	56
20	*	12	18	78	59	50

* No sample due to equipment malfunction.

Table 8

Status of Water Level, Salinity, and Temperature Recording Gages

Station No.	Data Periods Beginning Date	 Ending Date	Comments
TLR-7	1/ 1/90	1/23/90	
	1/23/90	3/ 9/90	Meter out for maintanence
	3/ 9/90	4/ 4/90	
	4/ 4/90	5/ 3/90	Data ends 4/16;low battery voltage
	5/ 3/90	6/12/90	
	6/12/90	8/ 2/90	
	8/ 2/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/14/90	
	11/14/90	12/12/90	
	12/12/90	12/31/90	
TLR-2	1/ 1/90	1/23/90	
	1/23/90	3/ 9/90	Meter out for maintanence
	3/ 9/89	4/ 4/90	
	4/ 4/90	5/ 3/90	
	5/ 3/90	6/12/90	Meter out for repairs
	6/12/90	8/ 2/90	Meter out for repairs
	8/ 2/90	8/28/90	Meter out for repairs
	8/28/90	9/25/90	Meter out for repairs
	9/25/90	11/14/90	Meter out for repairs
	11/14/90	12/12/90	
	12/12/90	12/31/90	
TLR-3	1/ 1/90	1/23/90	
	1/23/90	3/ 7/90	Meter out for maintanence
	3/ 7/90	4/ 4/90	
	4/ 4/90	5/ 4/90	
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/15/90	
	11/15/90	12/13/90	
	12/13/90	12/31/90	No data; low battery voltage
TLR-4	1/ 1/90	1/24/90	
	1/24/90	3/ 7/90	Meter out for maintanence
	3/ 7/90	4/ 4/90	
	4/ 4/90	5/ 3/90	
	5/ 3/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/15/90	
	11/15/90	12/13/90	
	12/13/90	12/31/90	

(Continued)

Table 8 (Concluded)

Station No.	Data Periods Beginning Date	Ending Date	Comments
TLR-5	1/ 1/90	1/24/90	
	1/24/90	3/ 6/90	Meter out for maintanence
	3/ 6/90	4/ 3/90	
	4/ 3/90	5/ 4/90	
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	Meter removed for repair
	8/ 1/90	8/28/90	Meter out for repair
	8/28/90	9/25/90	Meter out for repair
	9/25/90	11/15/90	Meter out for repair
	11/15/90	12/12/90	
	11/30/89	12/31/90	
TLR-6	1/ 1/90	1/23/90	
	1/23/90	3/ 6/90	Meter out for maintanence
	3/ 6/90	4/ 3/90	
	4/ 3/90	5/ 4/90	
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/14/90	
	11/14/90	12/13/90	
	12/13/90	12/31/90	

Table 9

Status of Automatic Water Samplers

Sampler No.	Sample Periods Start Date	End Date	Comments
WS7KB	1/ 1/90	1/23/90	Samples contaminated; no data
	1/23/90	3/ 8/90	Sampler out for maintanence
	3/ 8/90	4/ 4/90	
	4/ 4/90	5/ 3/90	
	5/ 3/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/14/90	
	11/14/90	12/12/90	No samples; low battery voltage
WS2KB	1/ 1/90	1/23/90	Samples contaminated; no data
	1/23/90	3/ 9 90	Sampler out for maintanence
	3/ 9/90	4/ 4/90	
	4/ 4/90	5/ 3/90	
	5/ 3/90	6/12/90	
	6/12/90	8/ 2/90	
	8/ 2/90	8/28/90	No samples; program error
	8/28/90	9/25/90	No samples; program error
	9/25/90	11/14/90	
	11/14/90	12/12/90	No samples; low battery voltage
WS3KB	1/ 1/90	1/23/90	Samples contaminated; no data
	1/23/90	3/ 7/90	Sampler out for maintanence
	3/ 7/90	4/ 4/90	
	4/ 4/90	5/ 4/90	
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	No samples
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/15/90	
	11/15/90	12/13/90	No samples; low battery voltage
WS4KB	1/ 1/90	1/24/90	Samples contaminated; no data
	1/24/90	3/ 7/90	Sampler out for maintanence
	3/ 7/90	4/ 4/90	
	4/ 4/90	5/ 3/90	
	5/ 3/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/15/90	
	11/15/90	12/13/90	No samples; low battery voltage

(Continued)

Table 9 (Concluded)

Sampler No.	Sample Periods Start Date	End Date	Comments
WS5KB	1/ 1/90	1/24/90	Samples contaminated; no data
	1/24/90	3/ 6/90	Sampler out for maintanence
	3/ 6/90	4/ 3/90	
	4/ 3/90	5/ 4/90	
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	
	8/28/90	9/25/90	
	9/25/90	11/14/90	
	11/14/90	12/12/90	No samples; low battery voltage
WS6KB	1/ 1/90	1/23/90	Samples contaminated; no data
	1/23/90	3/ 6/90	Sampler out for maintanence
	3/ 6/90	4/ 3/90	
	4/ 3/90	5/ 4/90	No samples; equipment malfunction
	5/ 4/90	6/12/90	
	6/12/90	8/ 1/90	
	8/ 1/90	8/28/90	Some samples; equipment malfunction
	8/28/90	9/25/90	
	9/25/90	11/14/90	
	11/14/90	12/13/90	No samples; low battery voltage

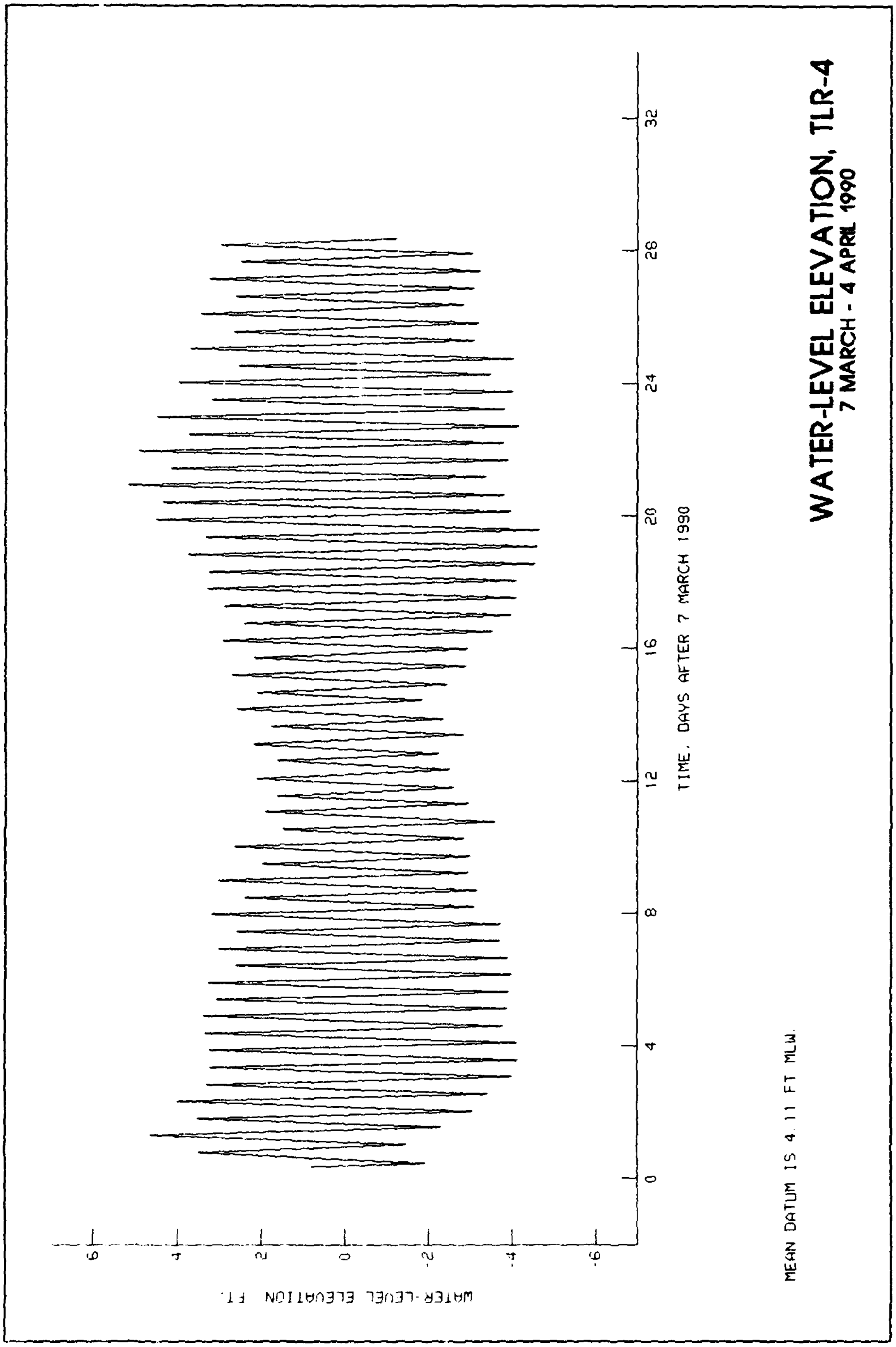
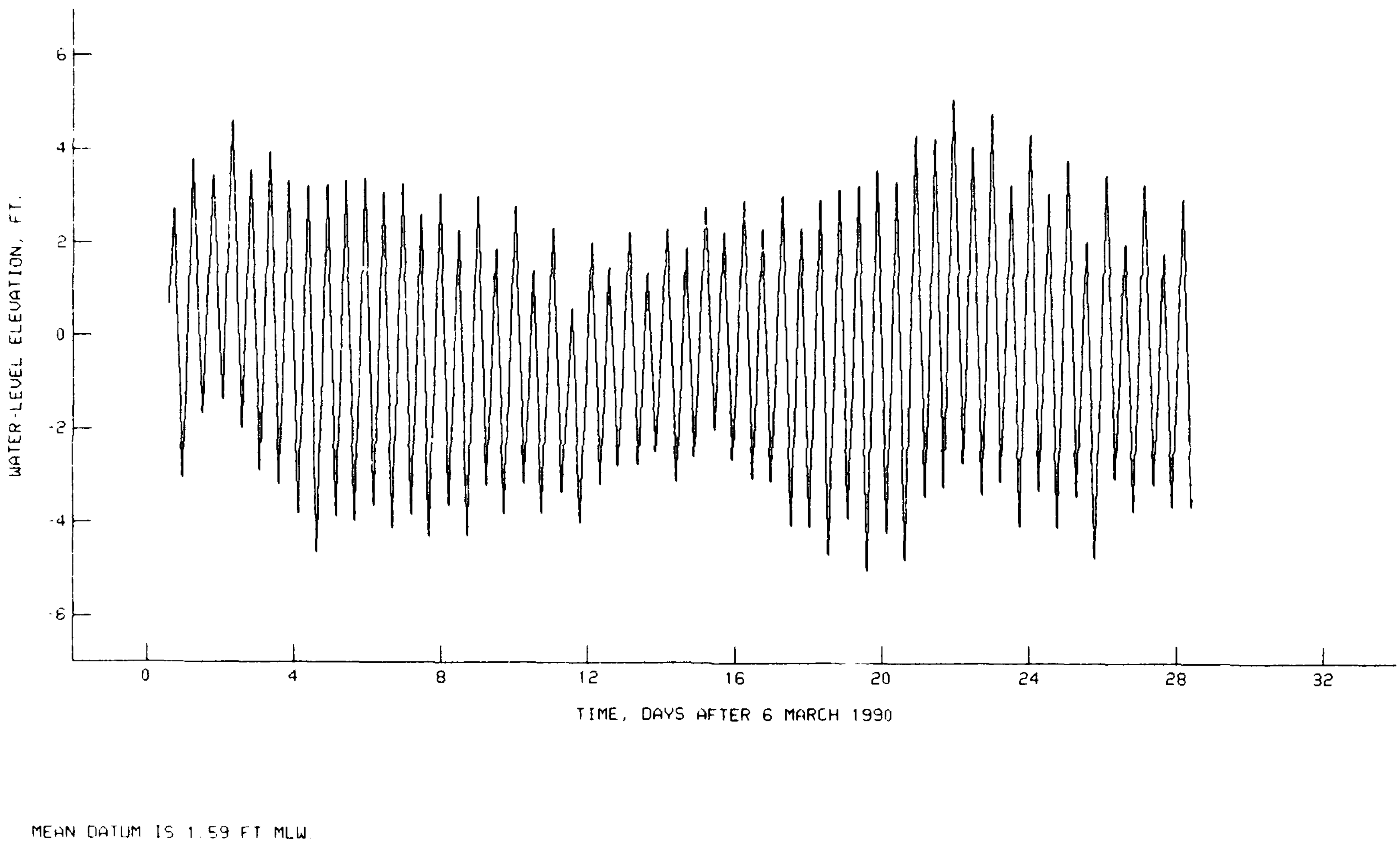
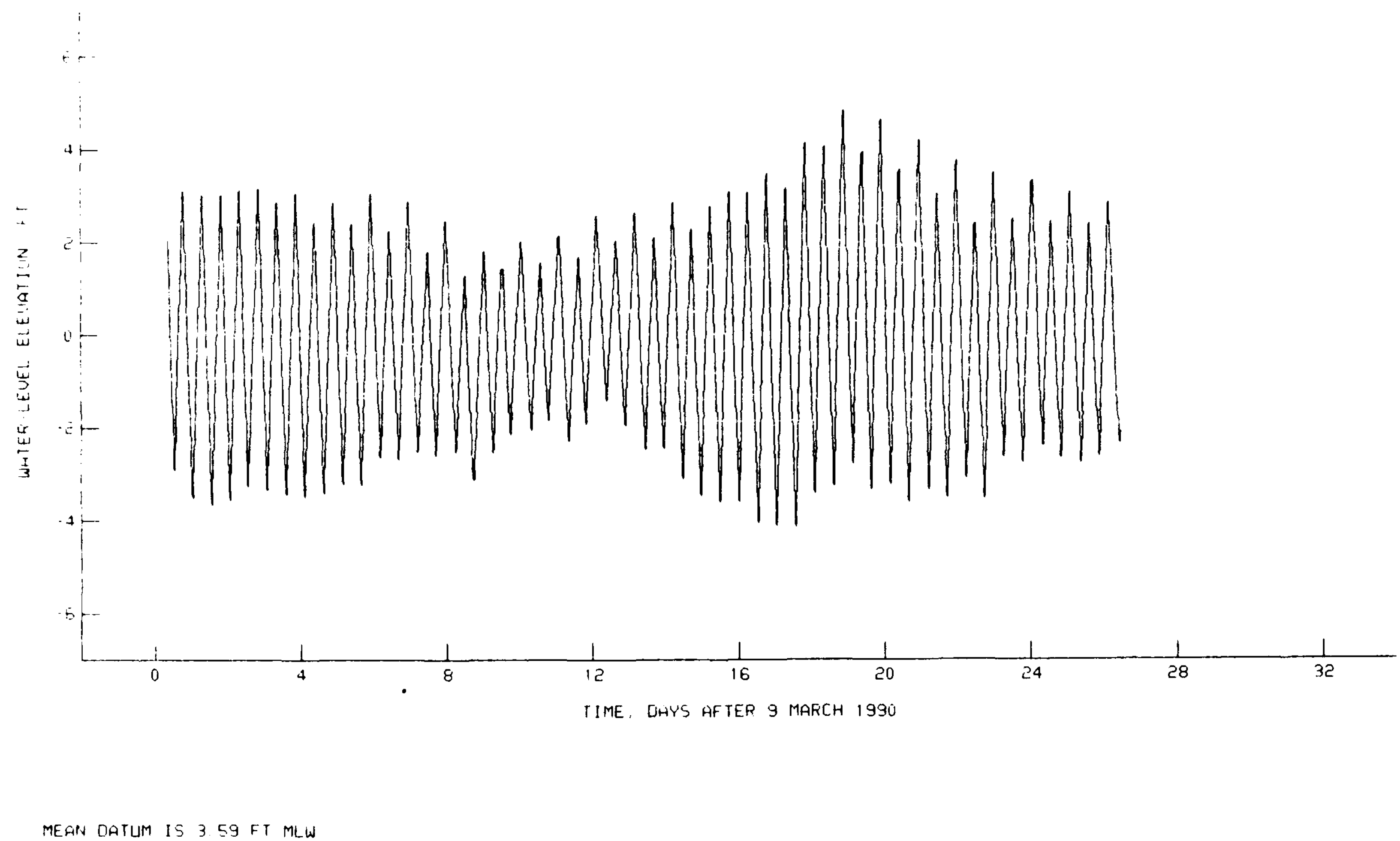

WATER-LEVEL ELEVATION, TLR-4
7 MARCH - 4 APRIL 1990
TIME, DAYS AFTER 7 MARCH 1990
WATER-LEVEL ELEVATION, FT.
MEAN DATUM IS 4.11 FT MLW.
0
4
8
12
16
20
24
28
32
.6
.4
.2
0
-.2
-.4
-.6

PLATE 1



WATER-LEVEL ELEVATION, TLR-5
6 MARCH - 3 APRIL 1990

PLATE 2



WATER-LEVEL ELEVATION, TLR-7
9 MARCH - 4 APRIL 1990

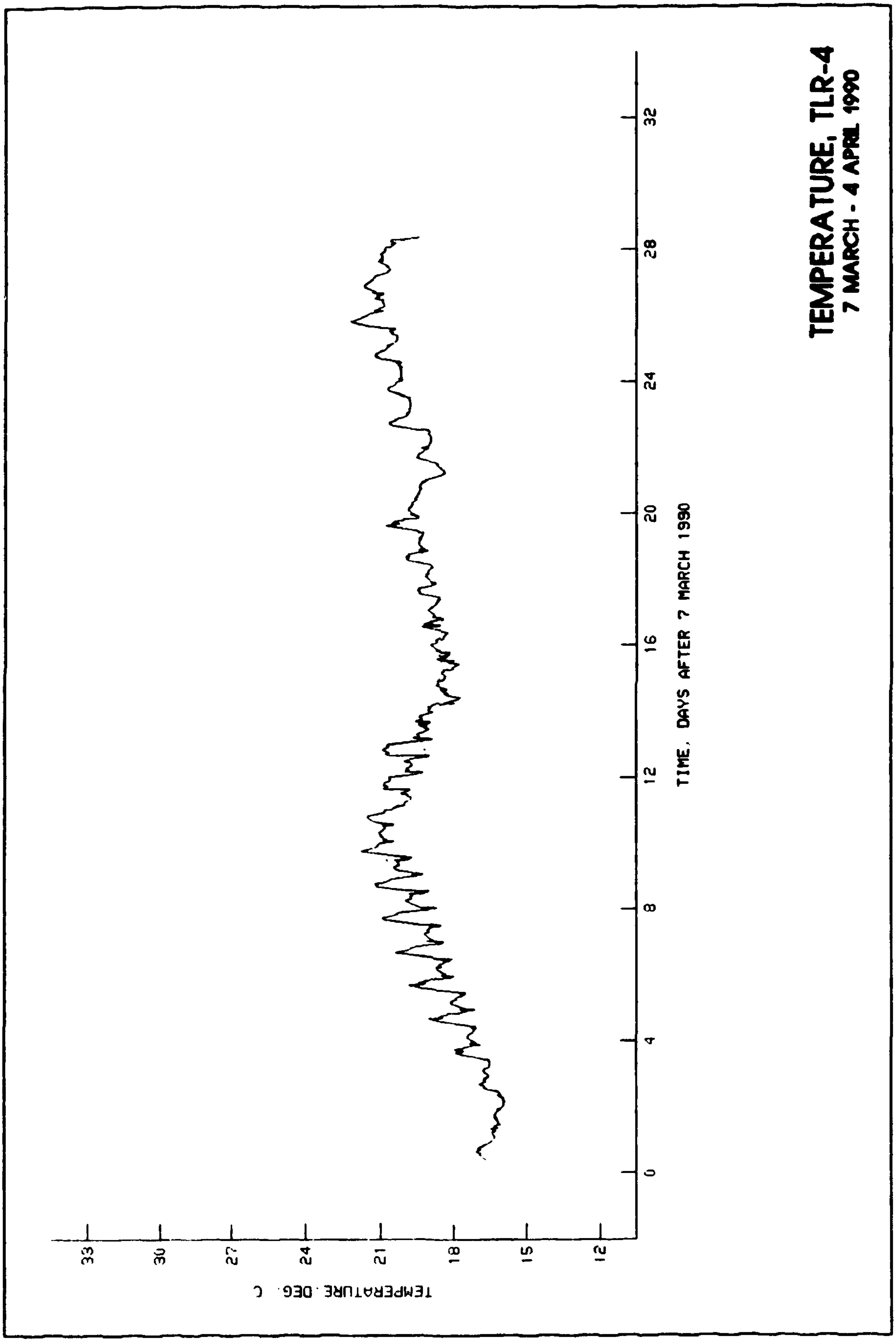
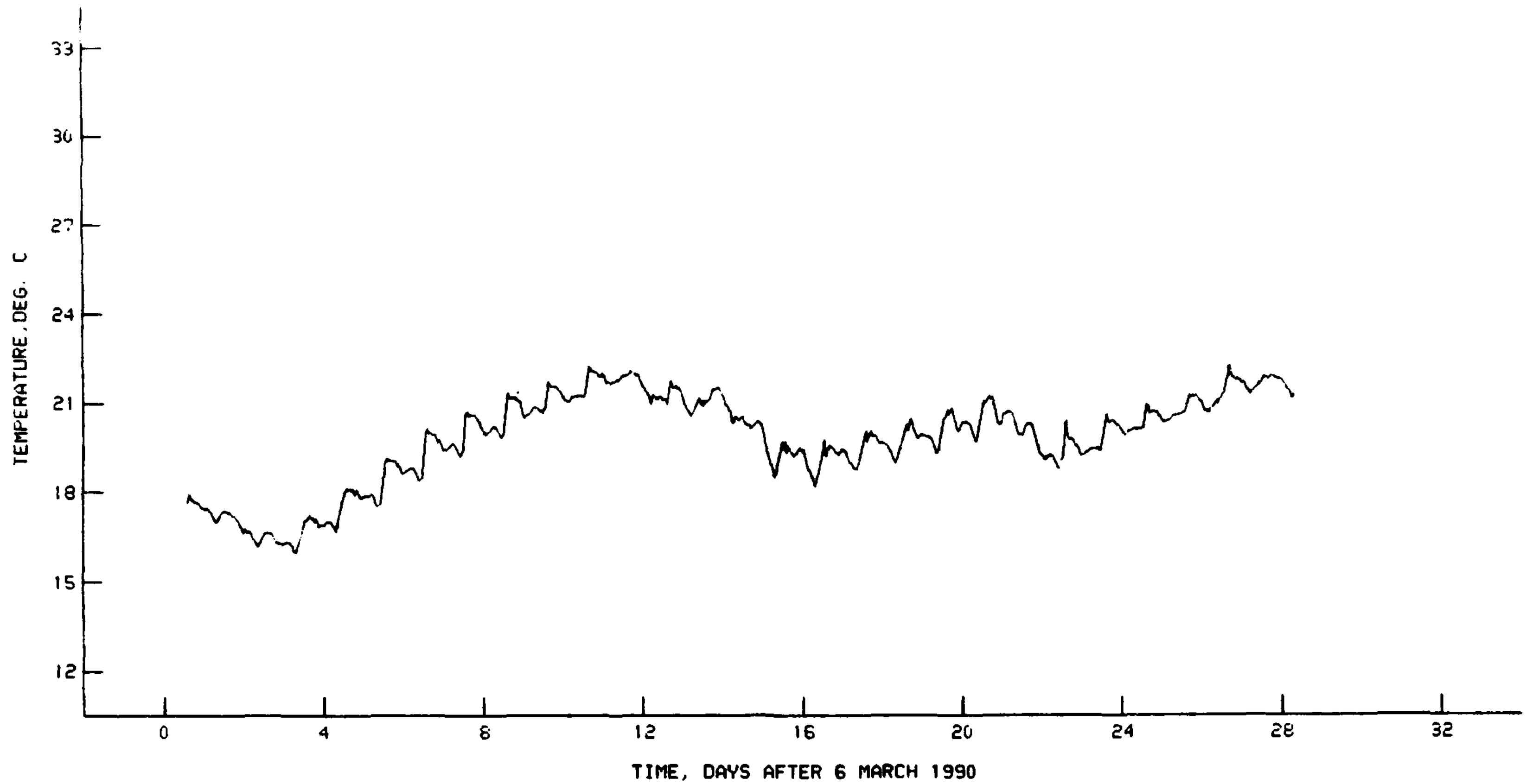
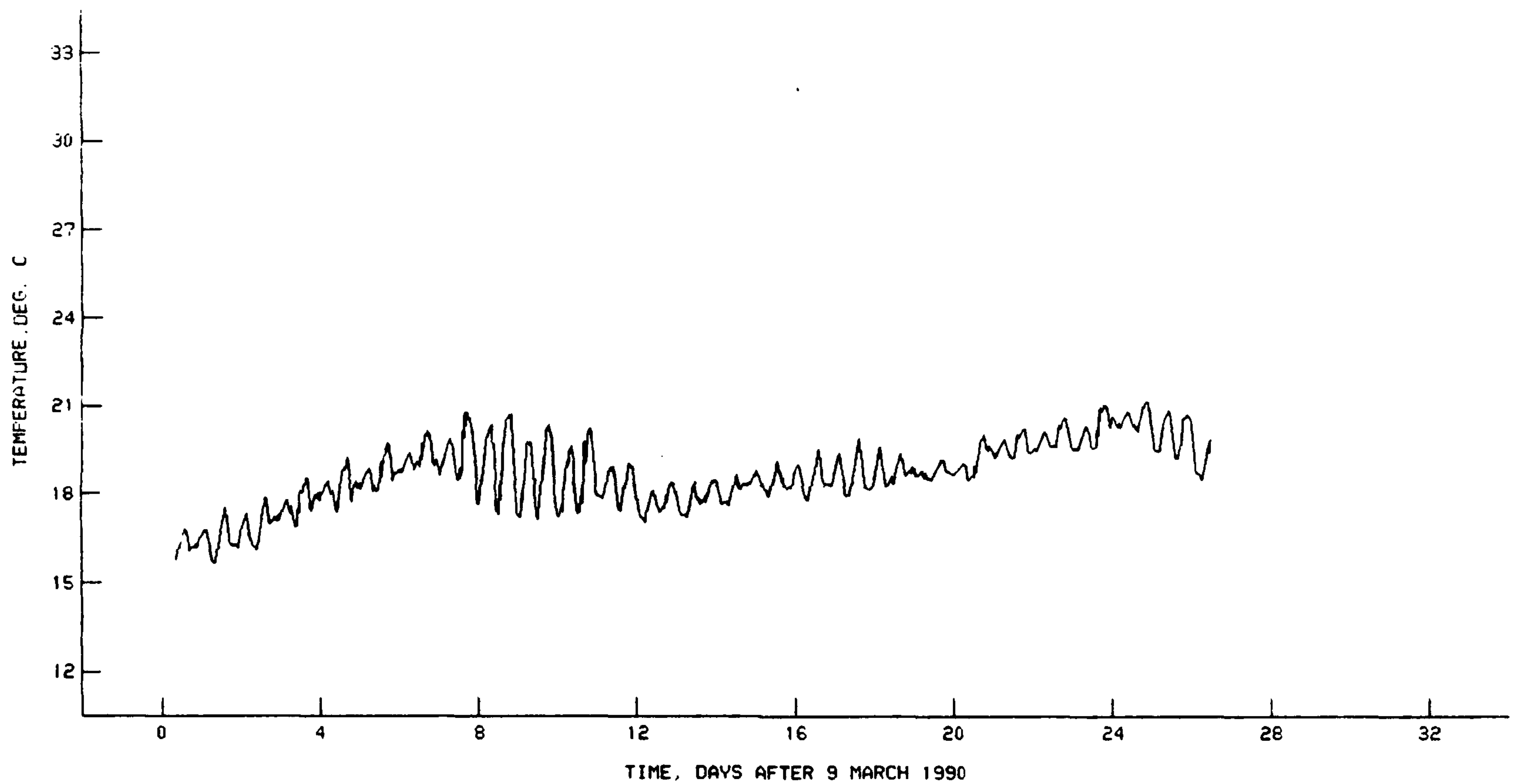

TEMPERATURE, TLR-4
7 MARCH - 4 APRIL 1990
TEMPERATURE, DEG. C
33
30
27
24
21
18
15
12
0
4
8
12
16
20
24
28
32
TIME, DAYS AFTER 7 MARCH 1990

PLATE 4



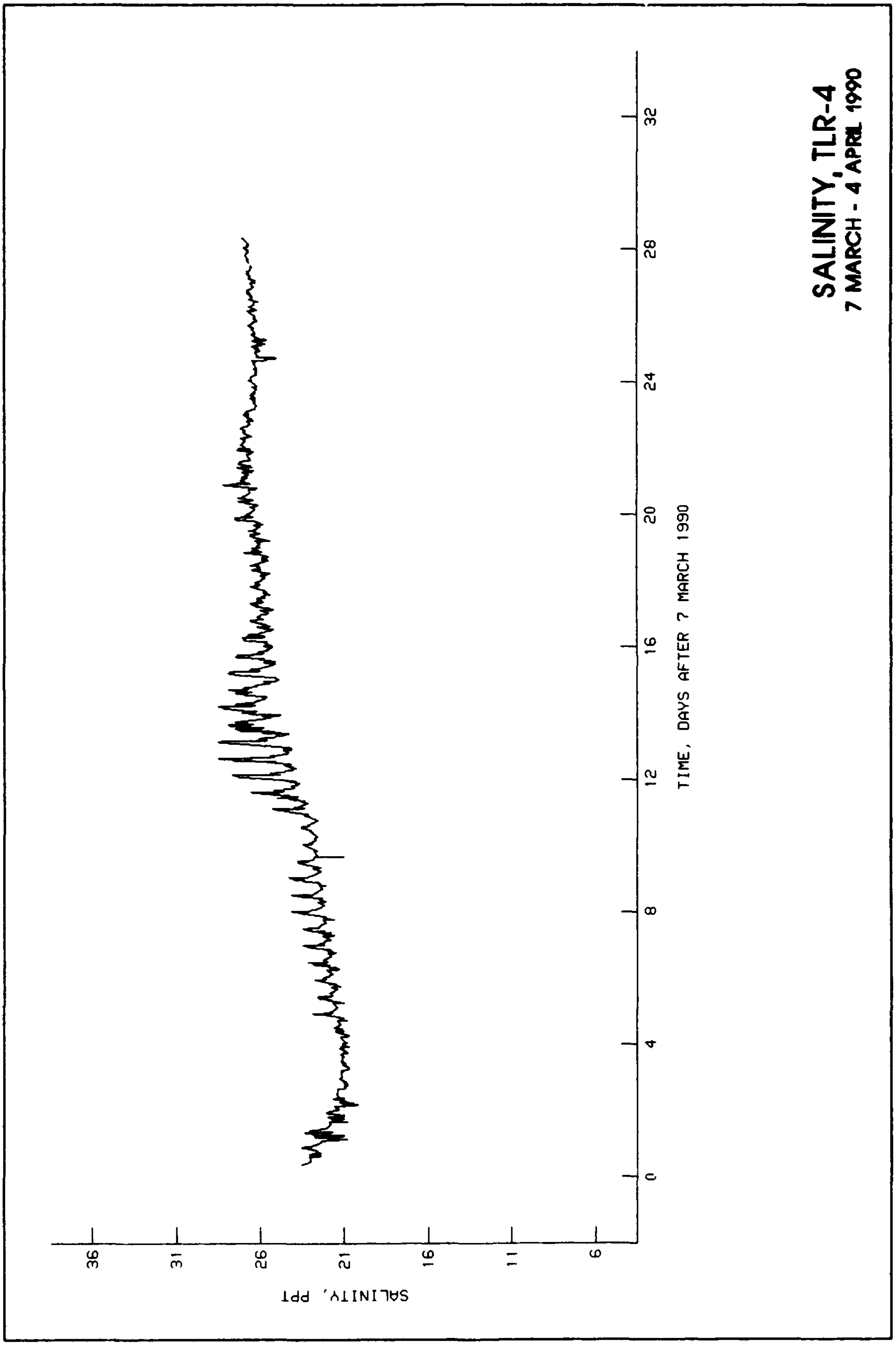
TEMPERATURE, TLR-5
6 MARCH - 3 APRIL 1990

PLATE 5

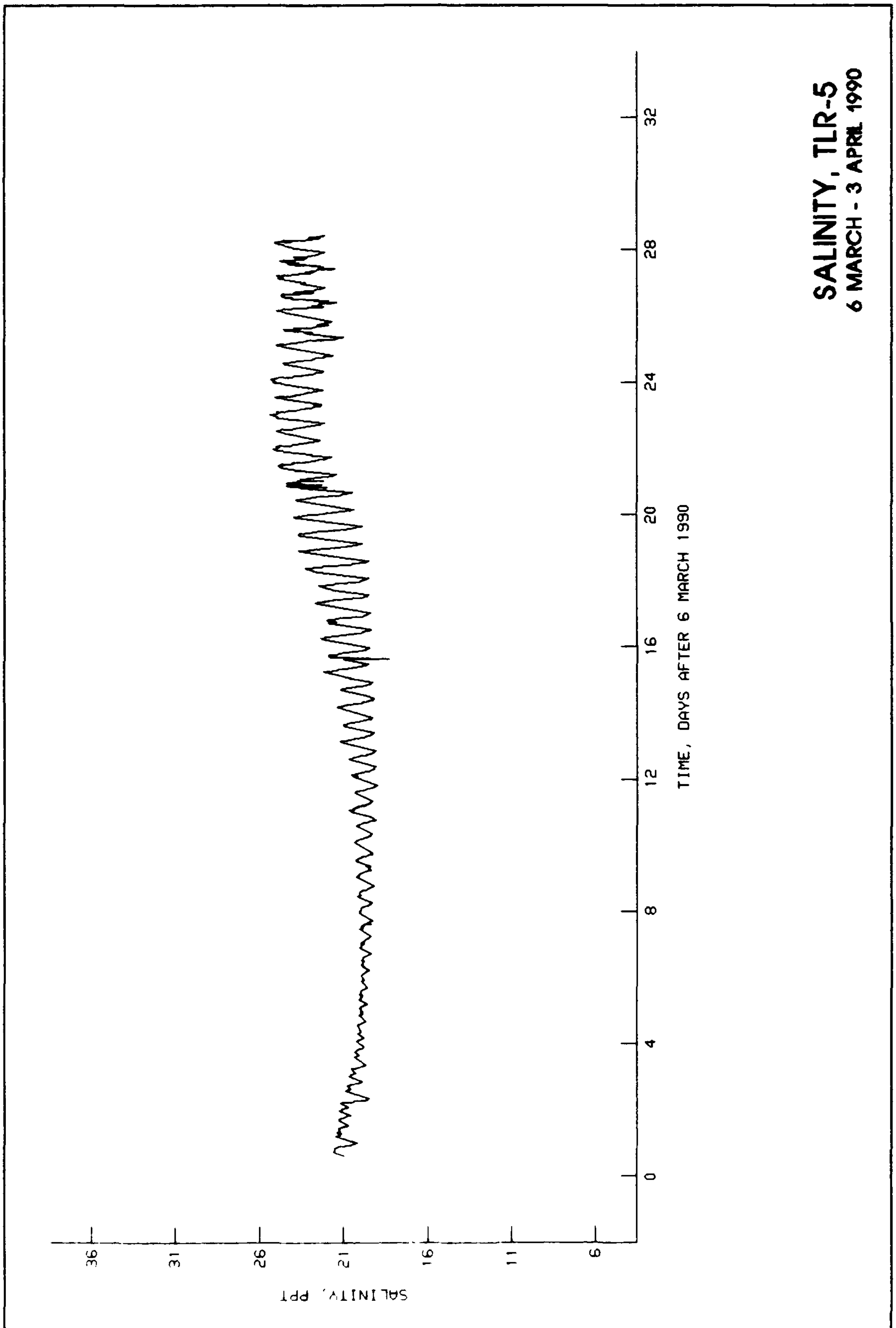


TEMPERATURE, TLR-7
9 MARCH - 4 APRIL 1990

PLATE 6

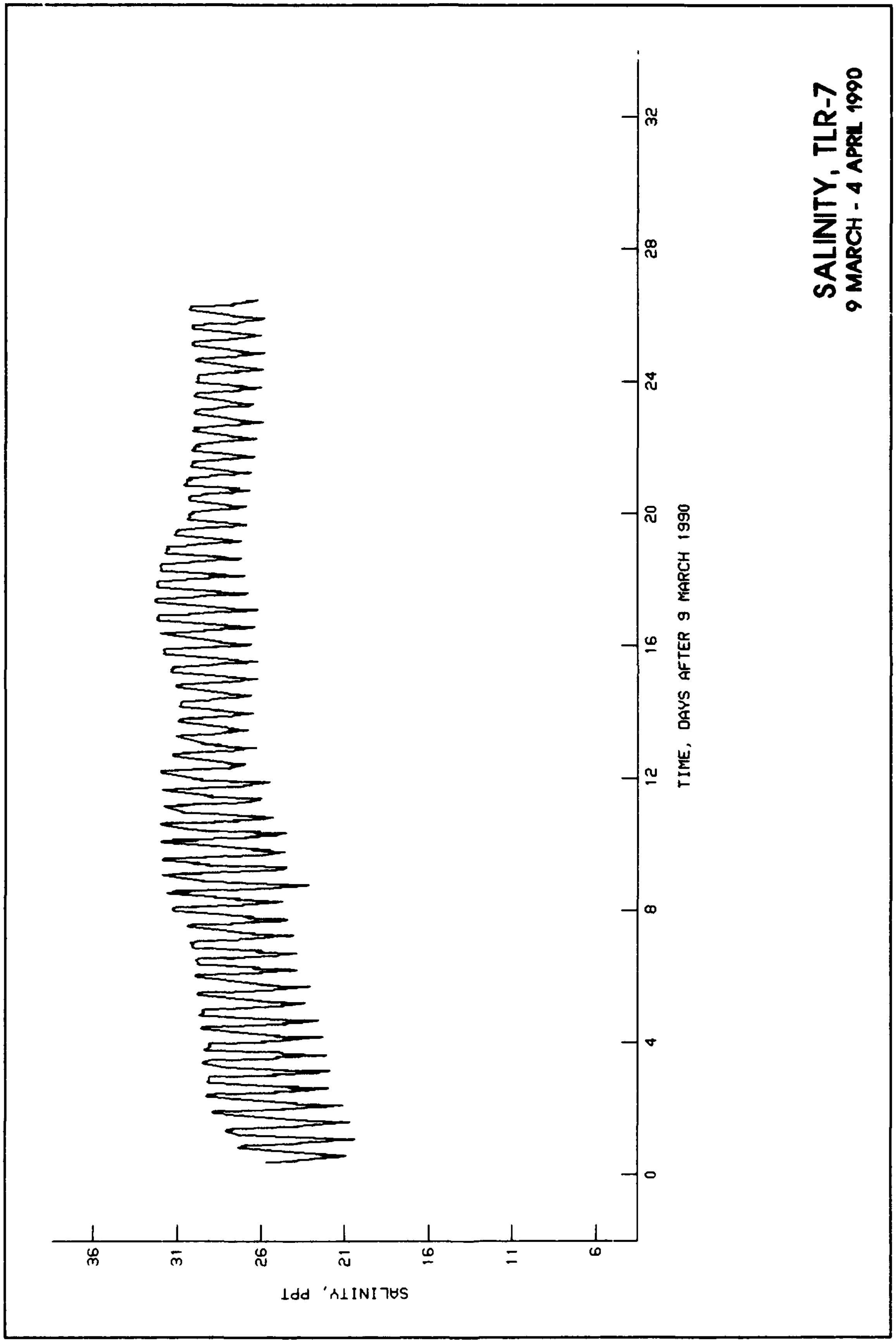


SALINITY, TLR-4
7 MARCH - 4 APRIL 1990

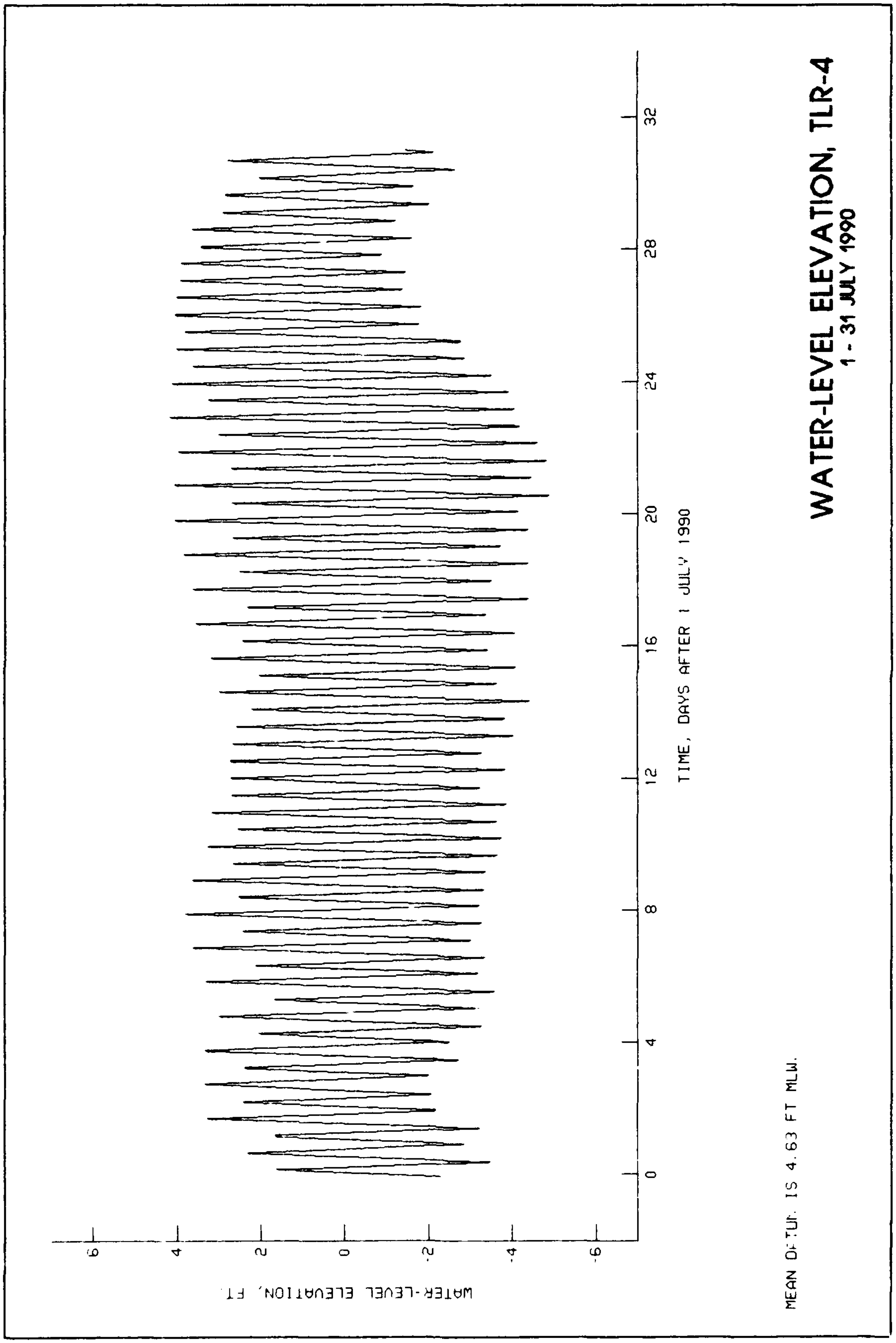


SALINITY, TLR-5
6 MARCH - 3 APRIL 1990

PLATE 8

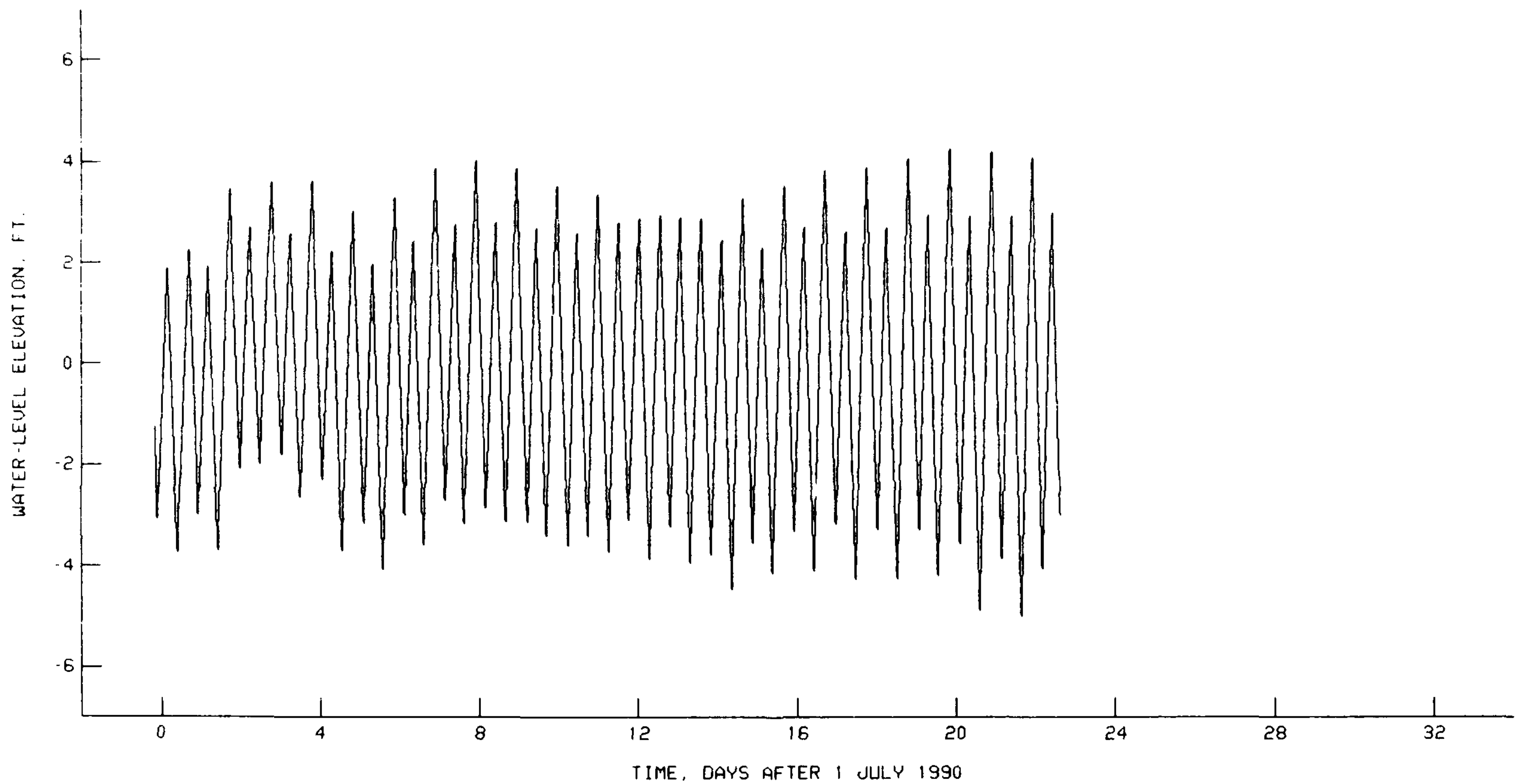


SALINITY, TLR-7
9 MARCH - 4 APRIL 1990



WATER-LEVEL ELEVATION, TLR-4
1 - 31 JULY 1990
TIME, DAYS AFTER 1 JULY 1990
WATER-LEVEL ELEVATION, FT
MEAN DATUM IS 4.63 FT MLW.

PLATE 10



MEAN DATUM IS 1.47 FT MLW.

WATER-LEVEL ELEVATION, TLR-5
1 - 31 JULY 1990

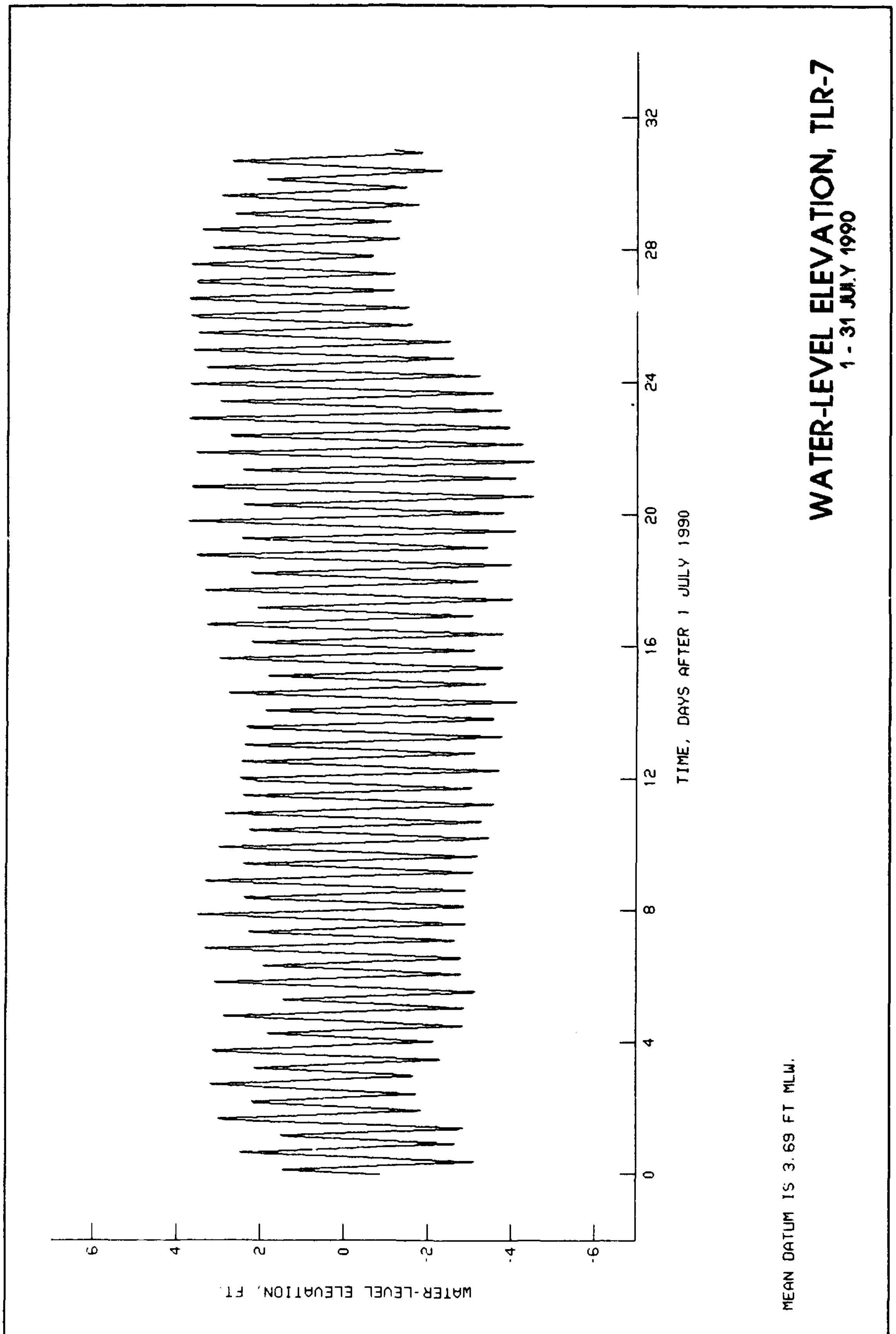
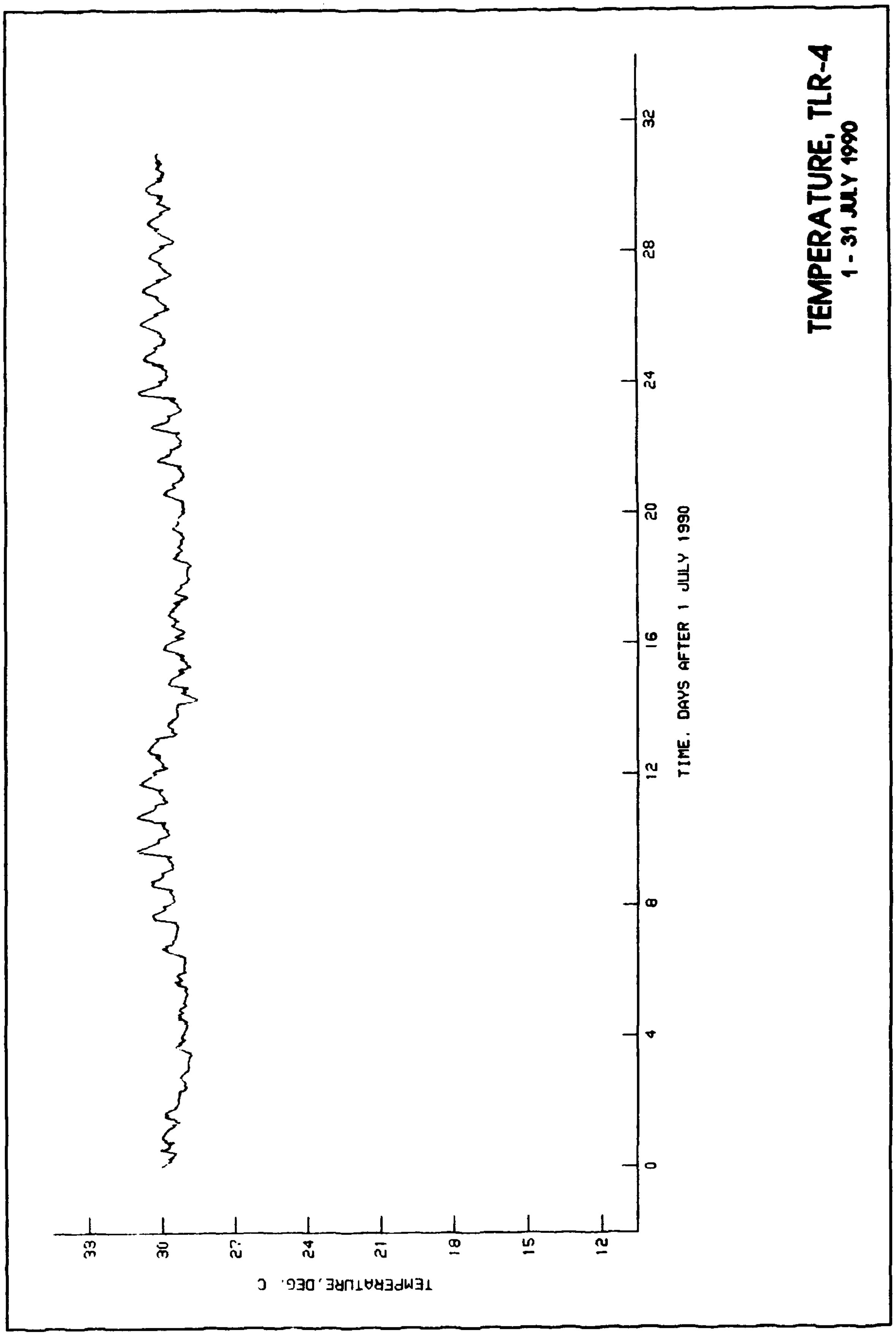

WATER-LEVEL ELEVATION, TLR-7
1 - 31 JULY 1990
WATER-LEVEL ELEVATION, FT
TIME, DAYS AFTER 1 JULY 1990
MEAN DATUM IS 3.69 FT MLW.
6
4
2
0
-2
-4
-6
0
4
8
12
16
20
24
28
32

PLATE 12



TEMPERATURE, TLR-4
1 - 31 JULY 1990
TIME, DAYS AFTER 1 JULY 1990
TEMPERATURE, DEG. C
0
4
8
12
16
20
24
28
32
12
15
18
21
24
27
30
33

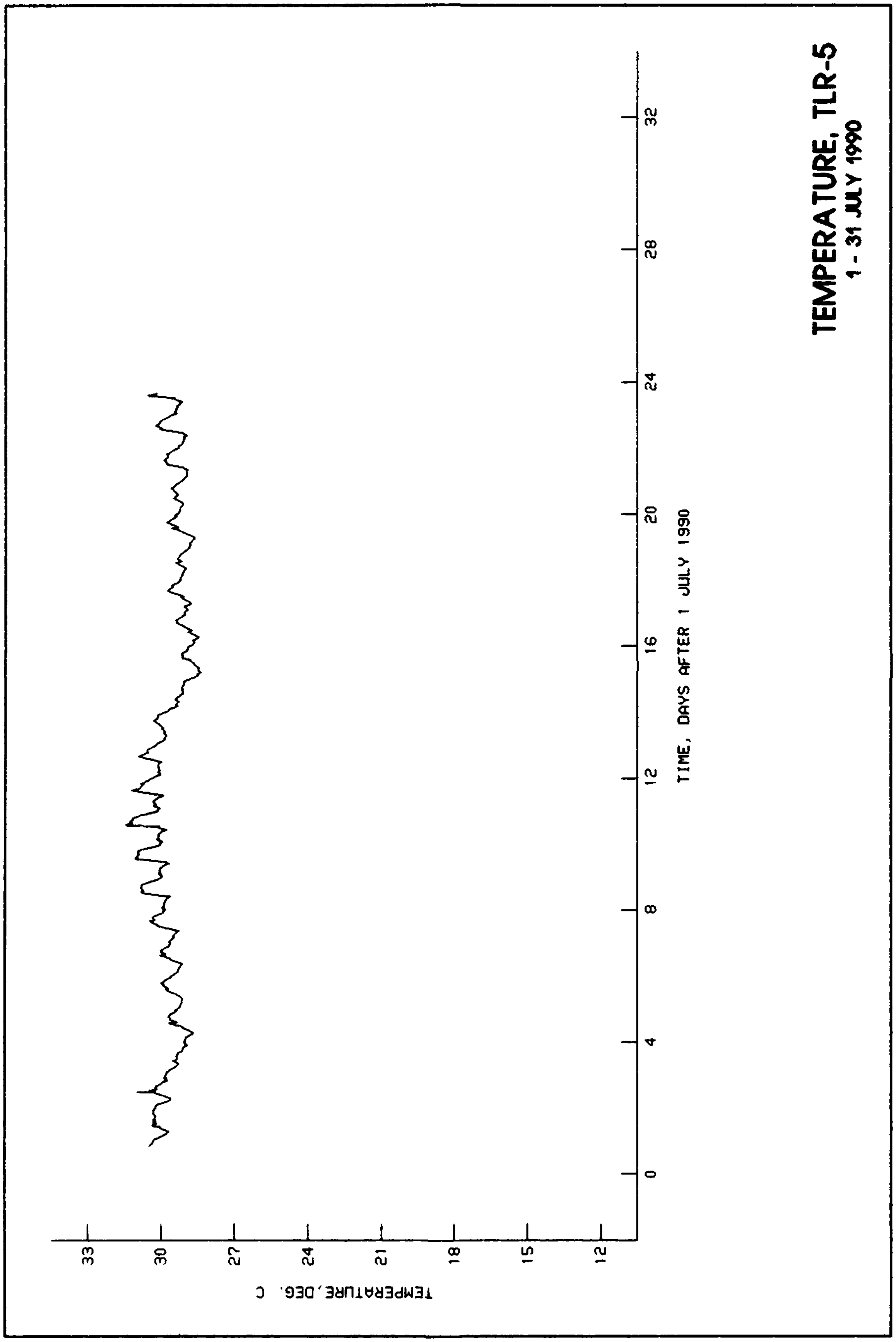
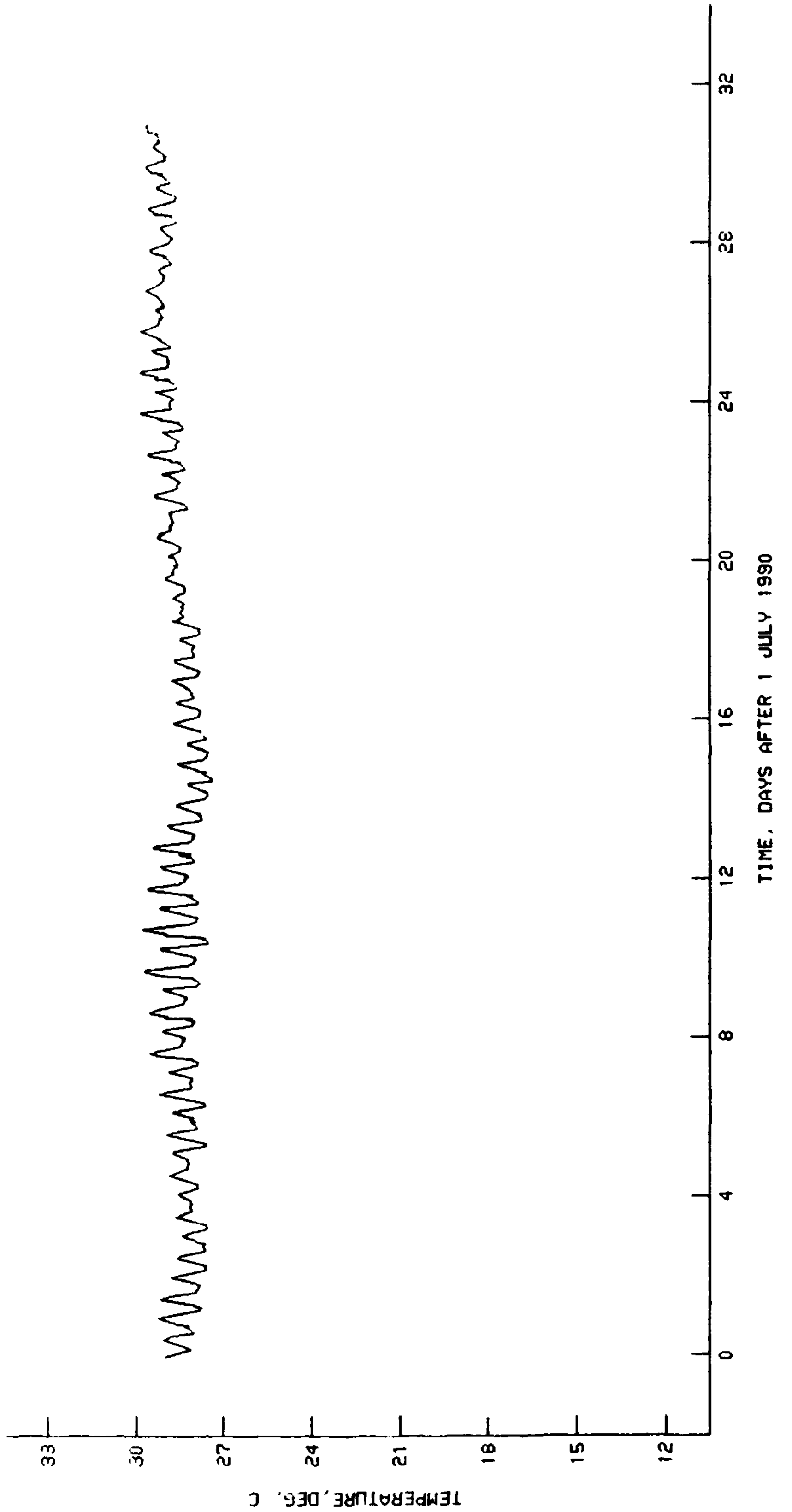

TEMPERATURE, TLR-5
1 - 31 JULY 1990
TEMPERATURE, DEG. C
TIME, DAYS AFTER 1 JULY 1990
12
15
18
21
24
27
30
33
0
4
8
12
16
20
24
28
32

PLATE 14



TEMPERATURE, TLR-7
1 - 31 JULY 1990

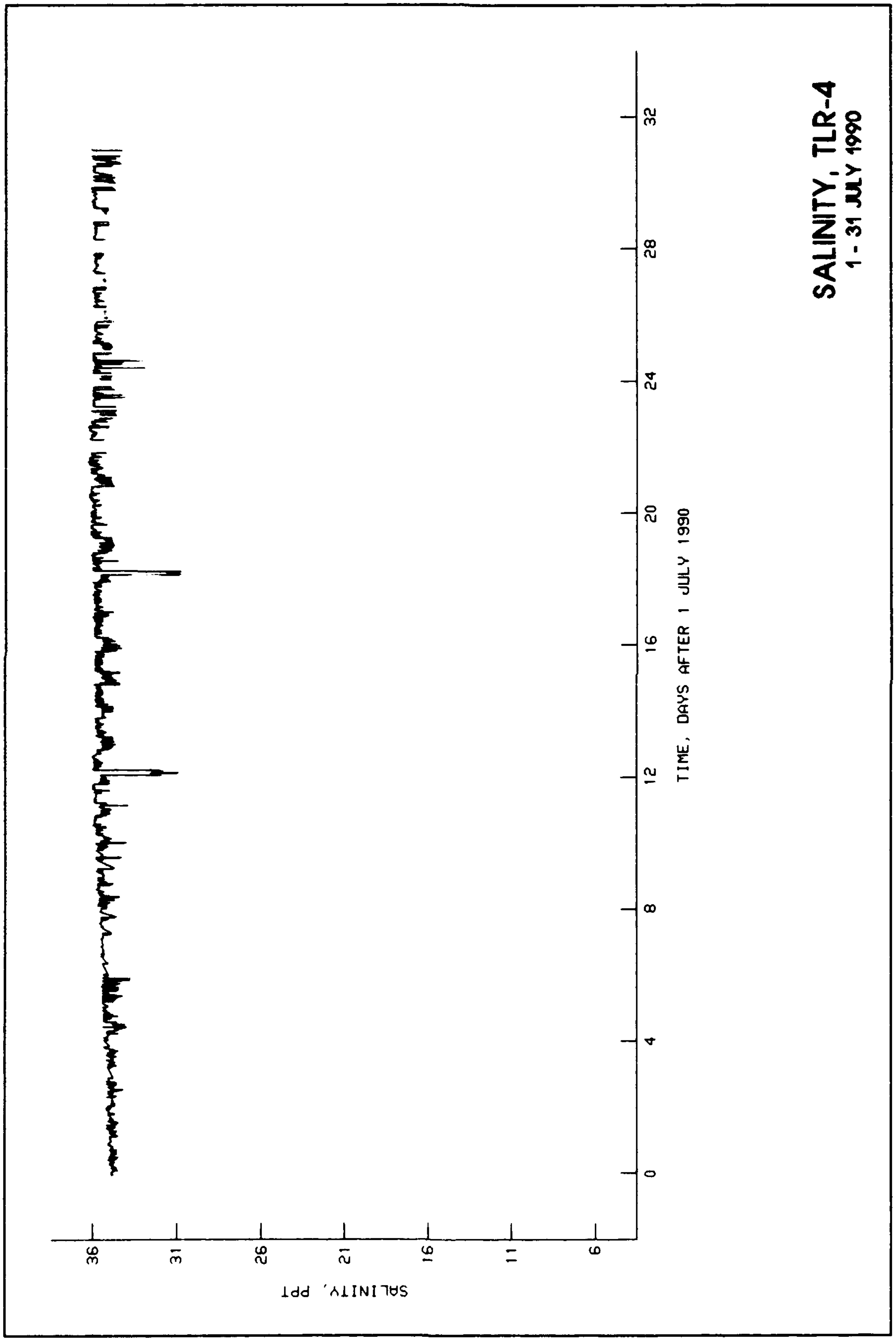
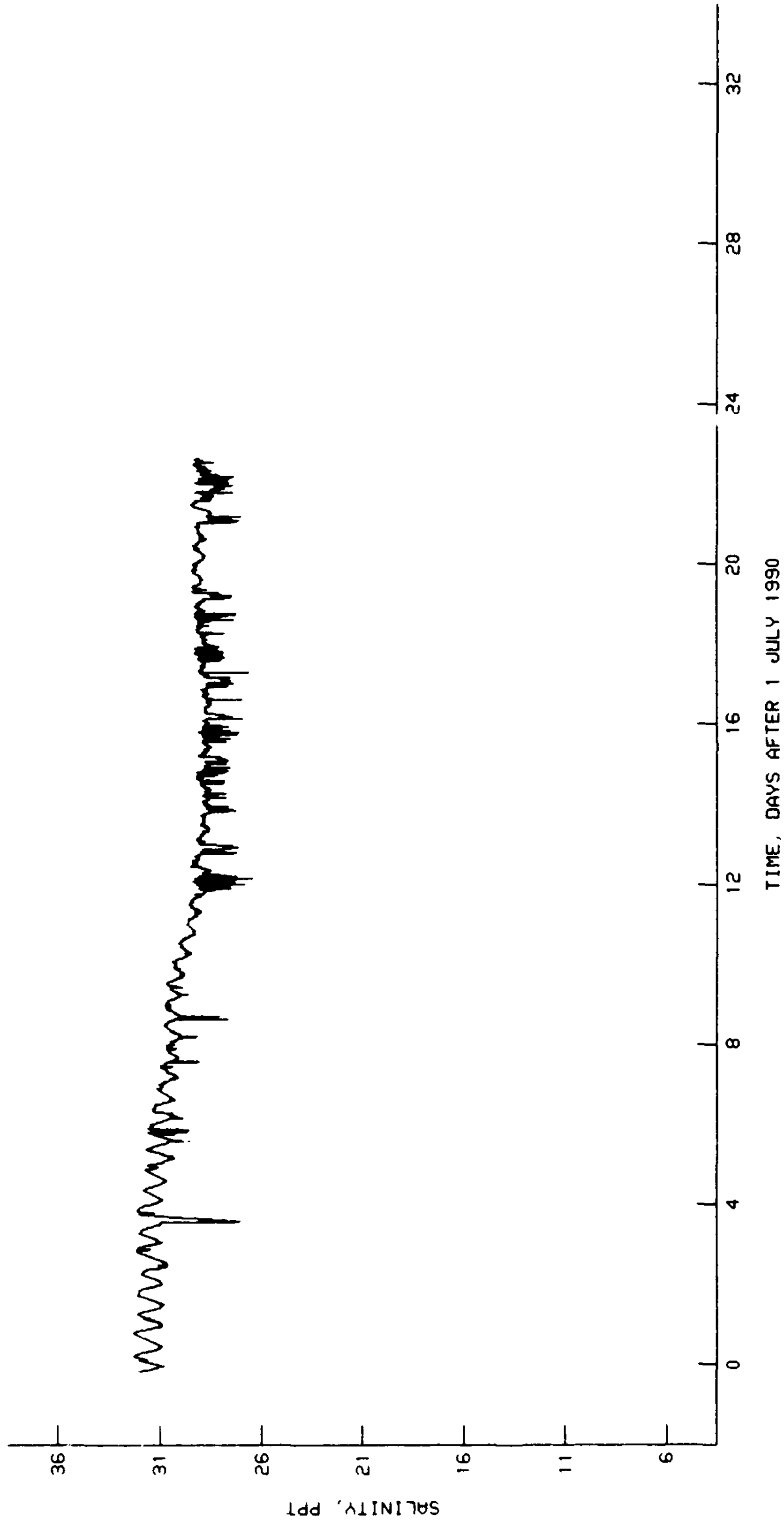

SALINITY, TLR-4
1 - 31 JULY 1990
SALINITY, PPT
36
31
26
21
16
11
6
TIME, DAYS AFTER 1 JULY 1990
0
4
8
12
16
20
24
28
32

PLATE 16



SALINITY, TLR-5
1 - 31 JULY 1990

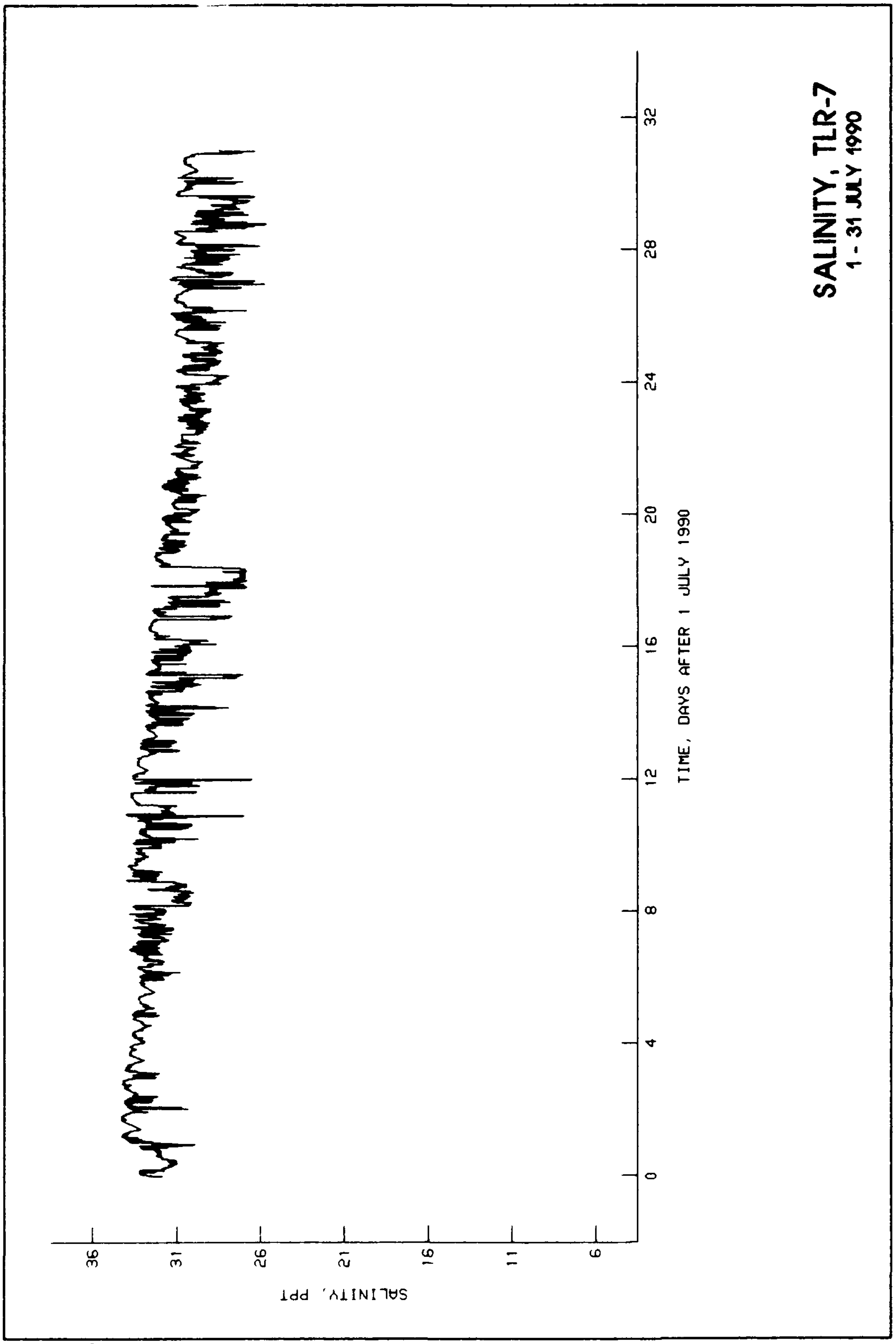
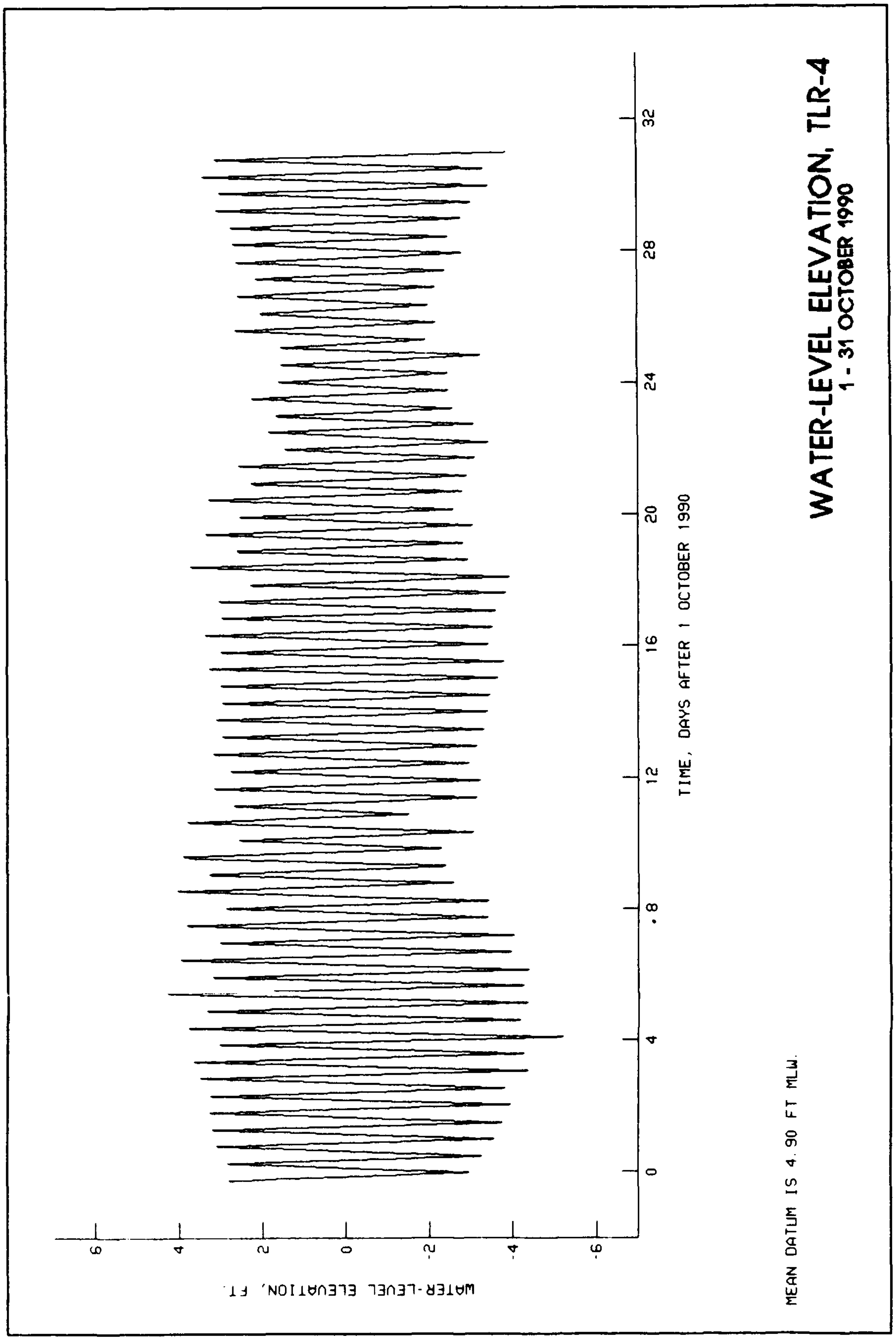
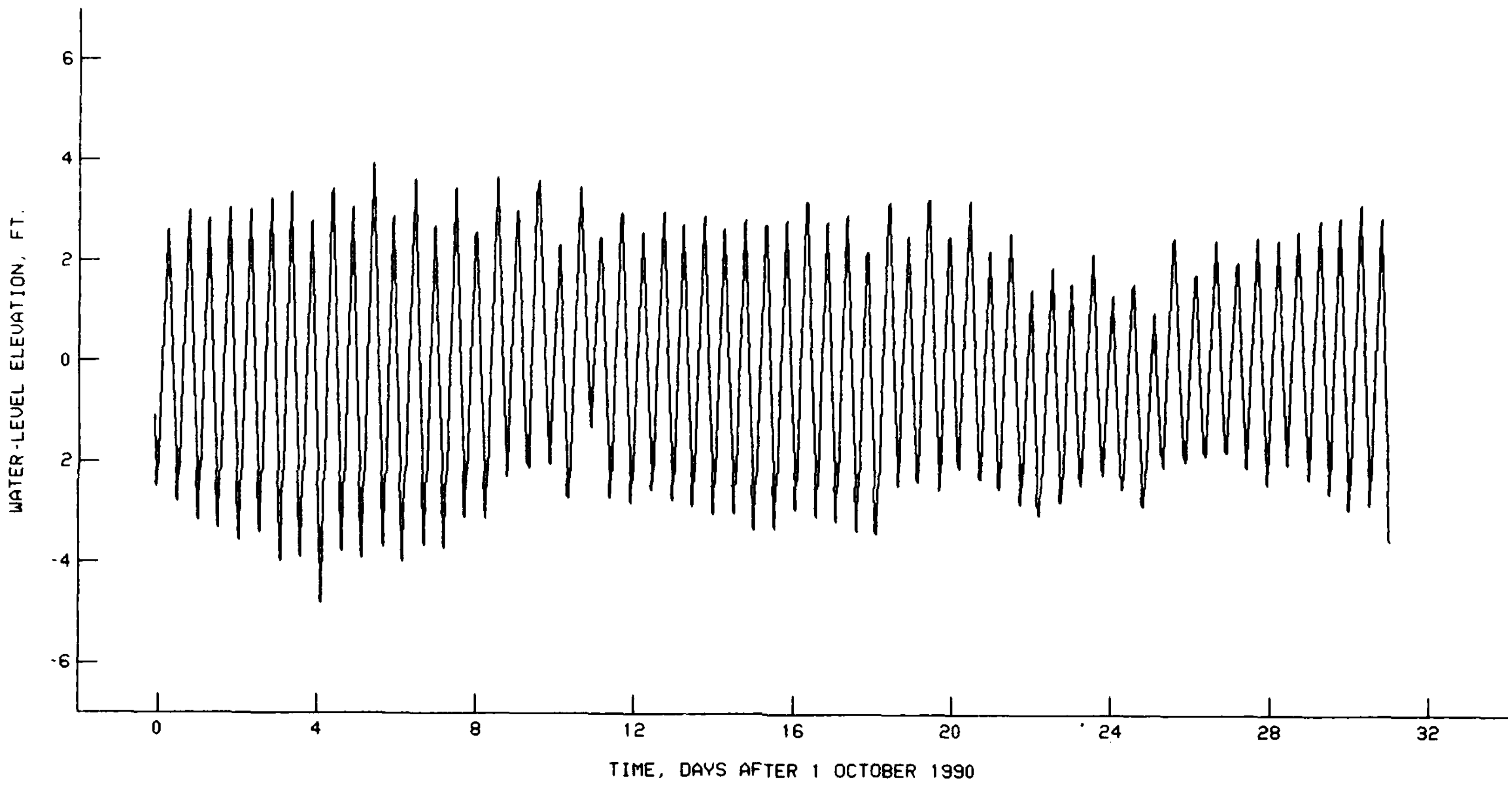

SALINITY, TLR-7
1 - 31 JULY 1990
TIME, DAYS AFTER 1 JULY 1990
SALINITY, PPT
0
4
8
12
16
20
24
28
32
6
11
16
21
26
31
36

PLATE 18



WATER-LEVEL ELEVATION, TLR-4
1 - 31 OCTOBER 1990
WATER-LEVEL ELEVATION, FT.
6
4
2
0
-2
-4
-6
0
4
8
12
16
20
24
28
32
TIME, DAYS AFTER 1 OCTOBER 1990
MEAN DATUM IS 4.90 FT MLW.

PLATE 20



MEAN DATUM IS 4.14 FT MLW.

WATER-LEVEL ELEVATION, TLR-7
1 - 31 OCTOBER 1990

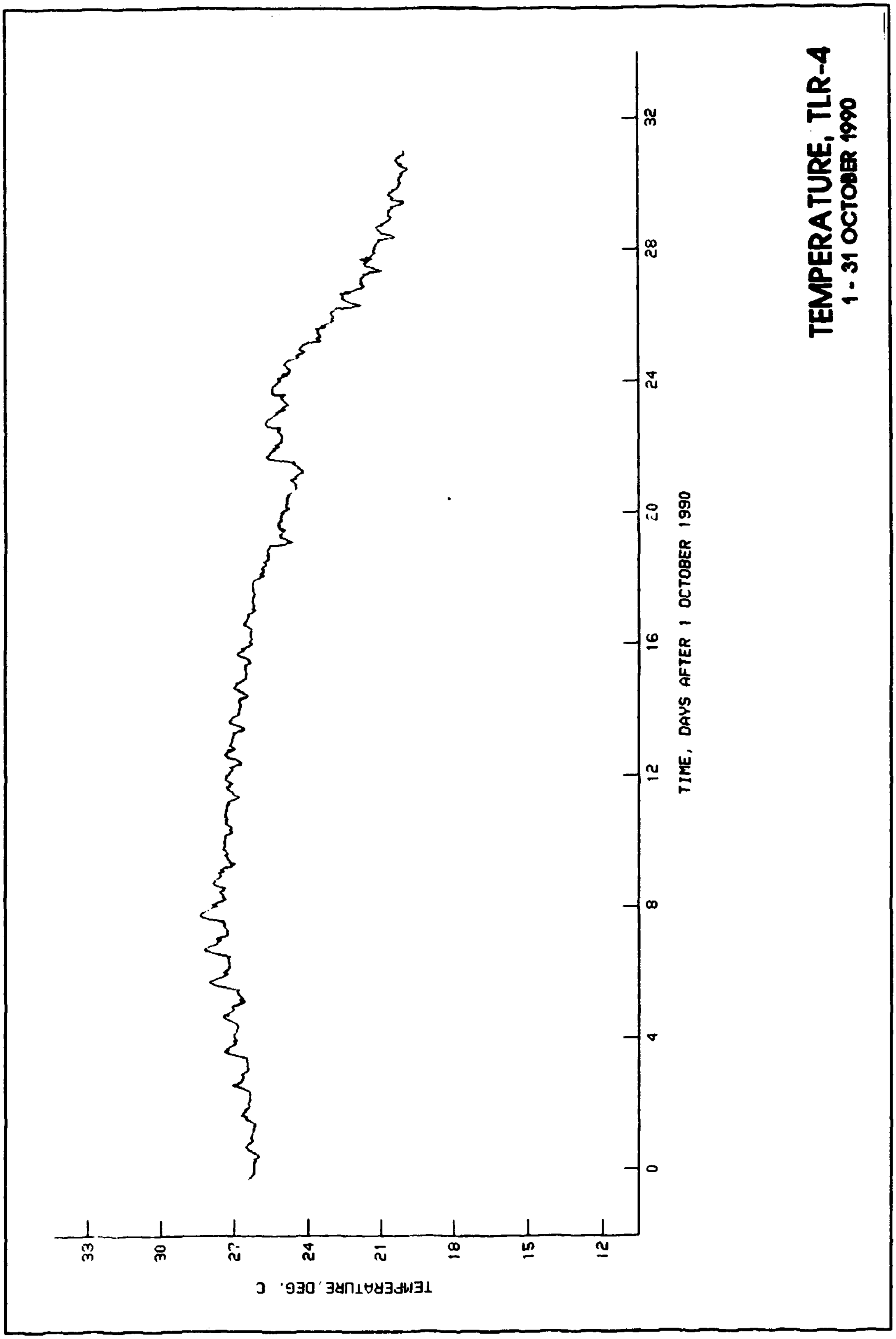
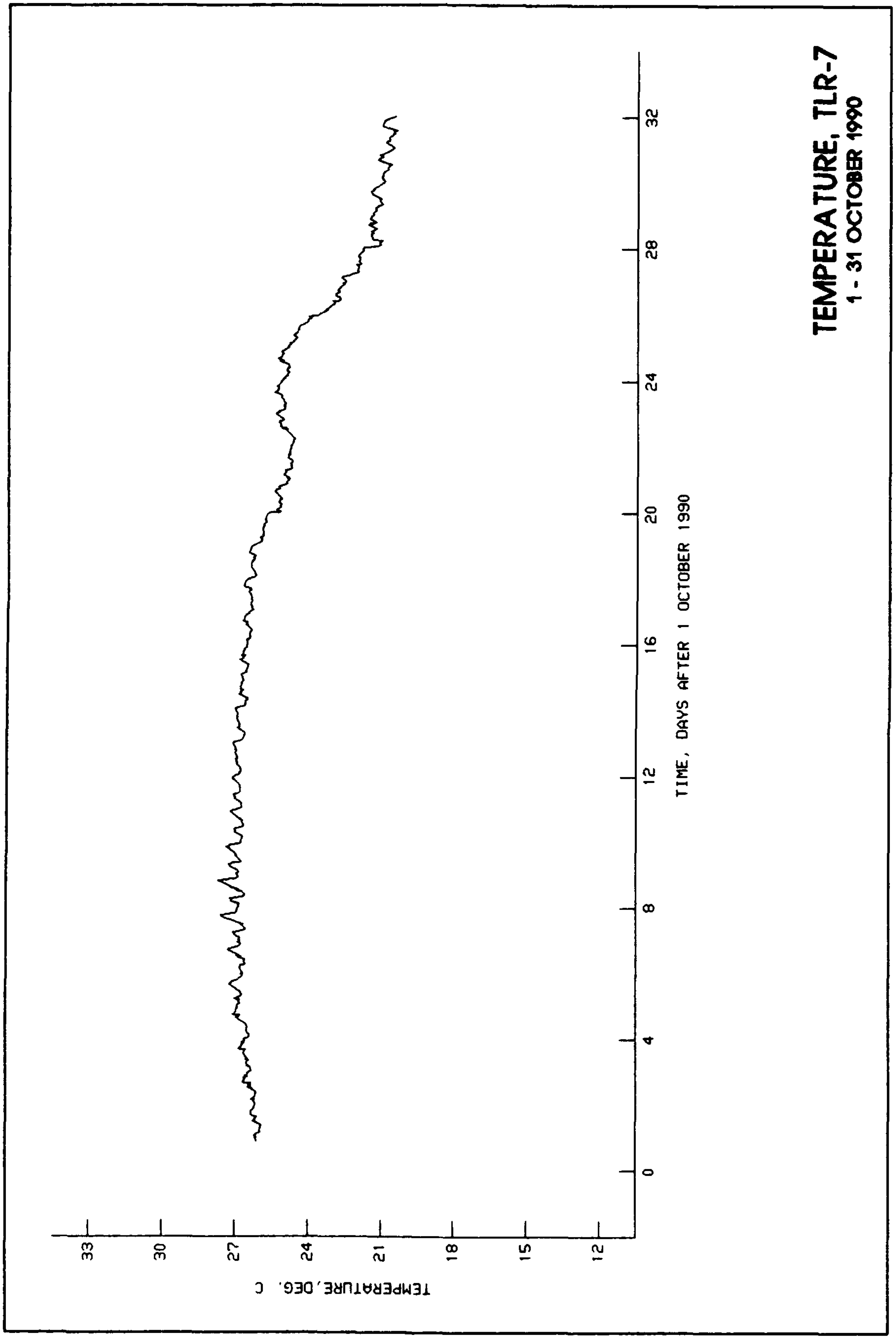

TEMPERATURE, TLR-4
1 - 31 OCTOBER 1990
TIME, DAYS AFTER 1 OCTOBER 1990
0
4
8
12
16
20
24
28
32
TEMPERATURE, DEG. C
12
15
18
21
24
27
30
33

PLATE 21



TEMPERATURE, TLR-7
1 - 31 OCTOBER 1990

PLATE 22

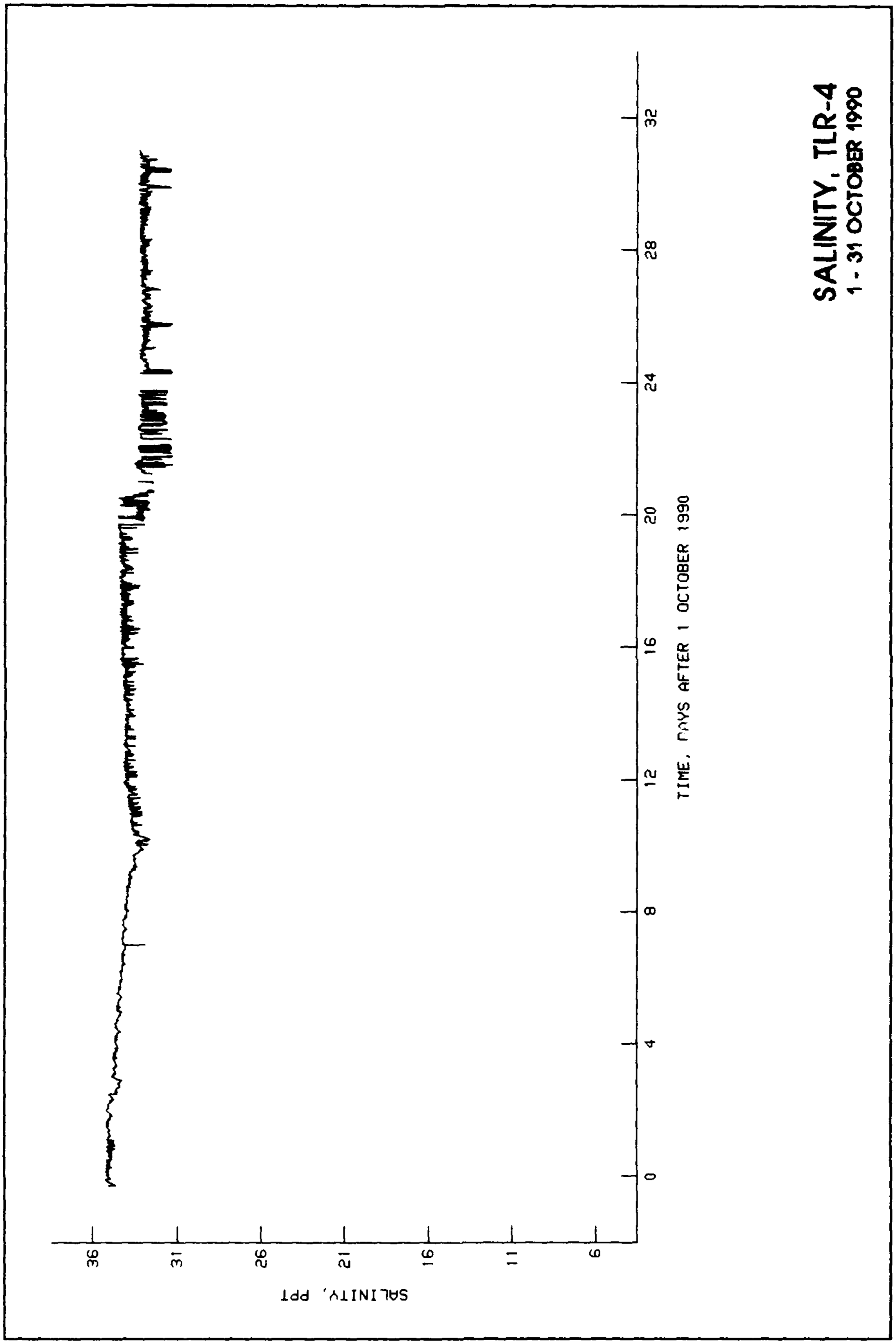

SALINITY, TLR-4
1 - 31 OCTOBER 1990
SALINITY, PPT
TIME, DAYS AFTER 1 OCTOBER 1990
36
31
26
21
16
11
6
0
4
8
12
16
20
24
28
32

PLATE 23

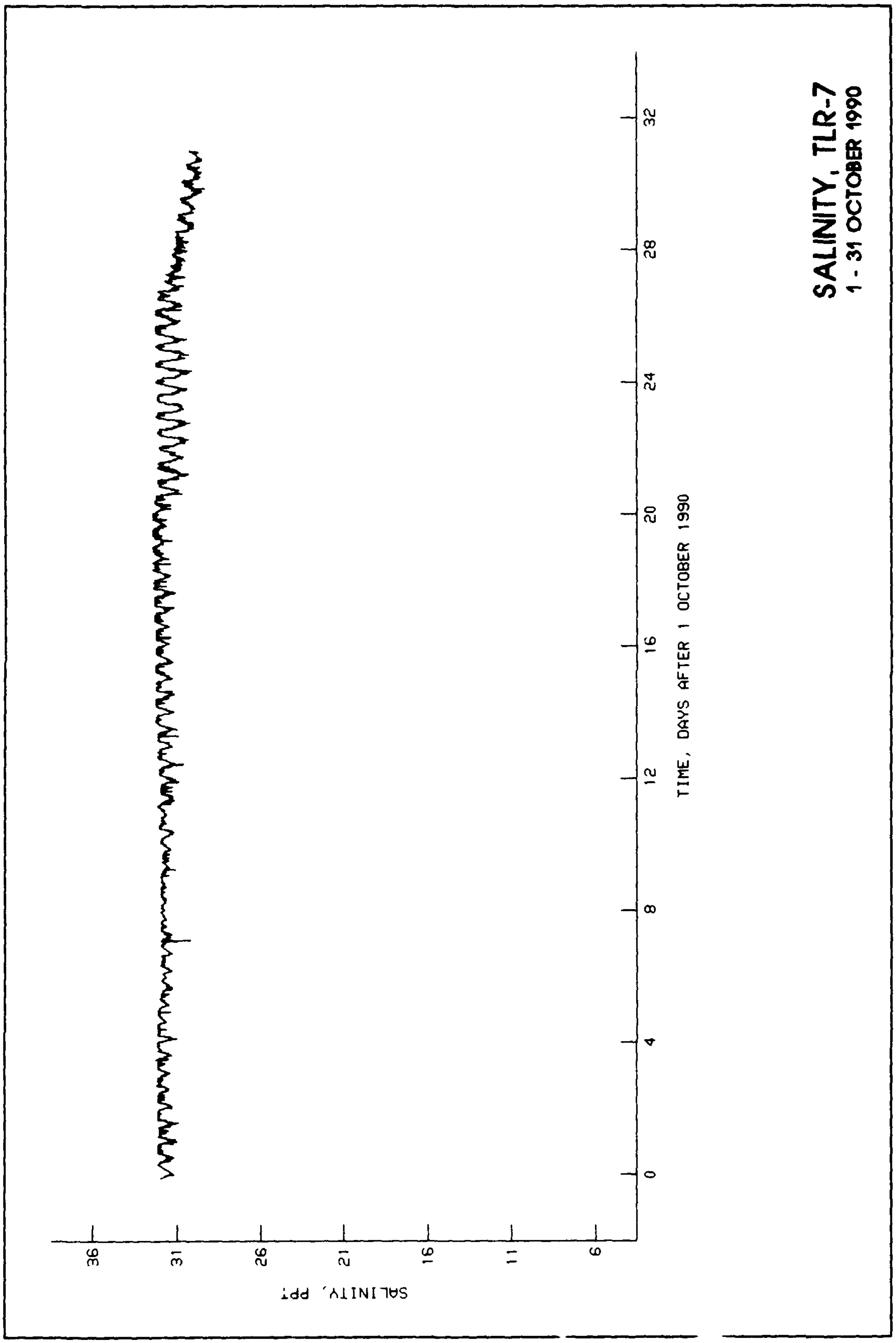
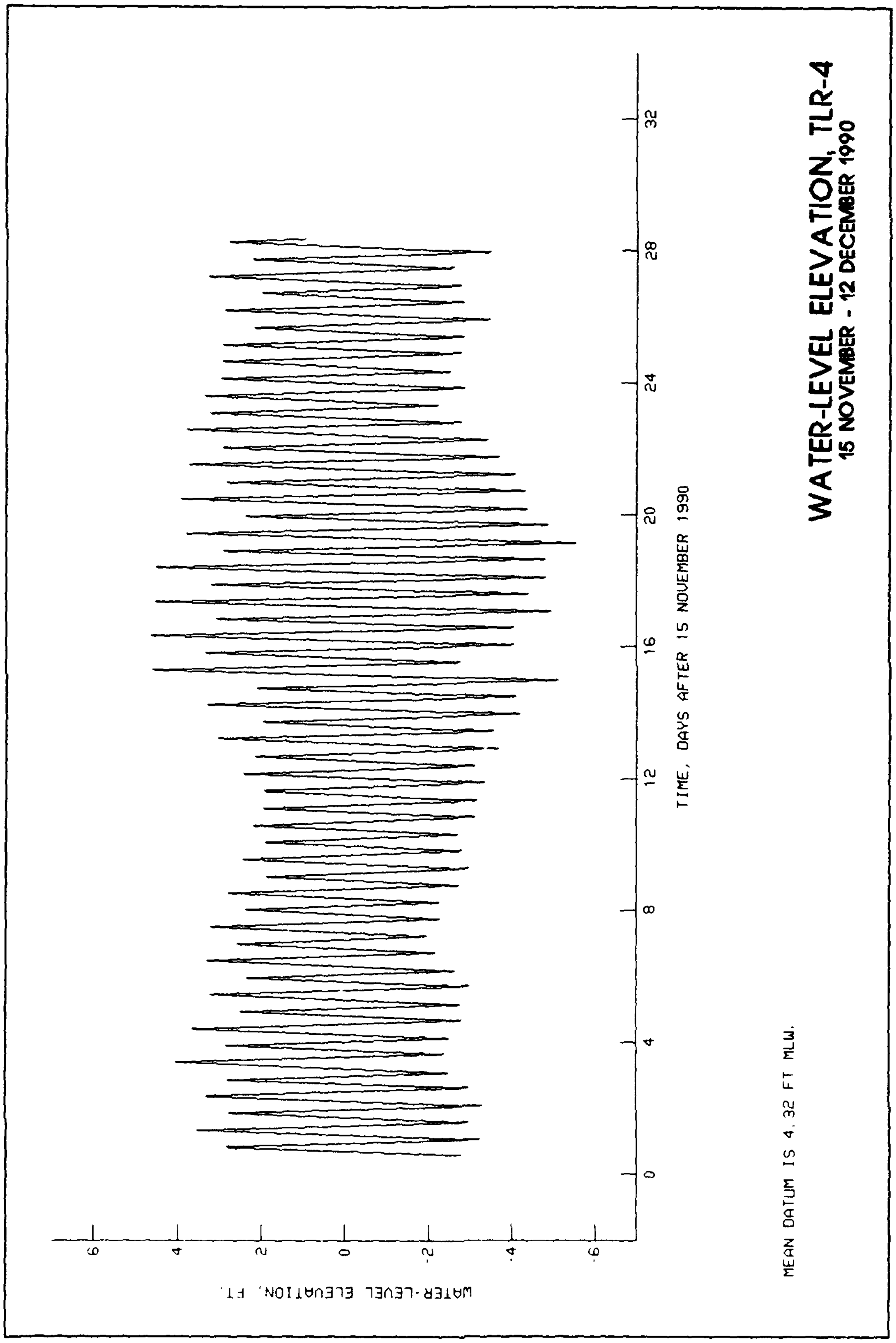
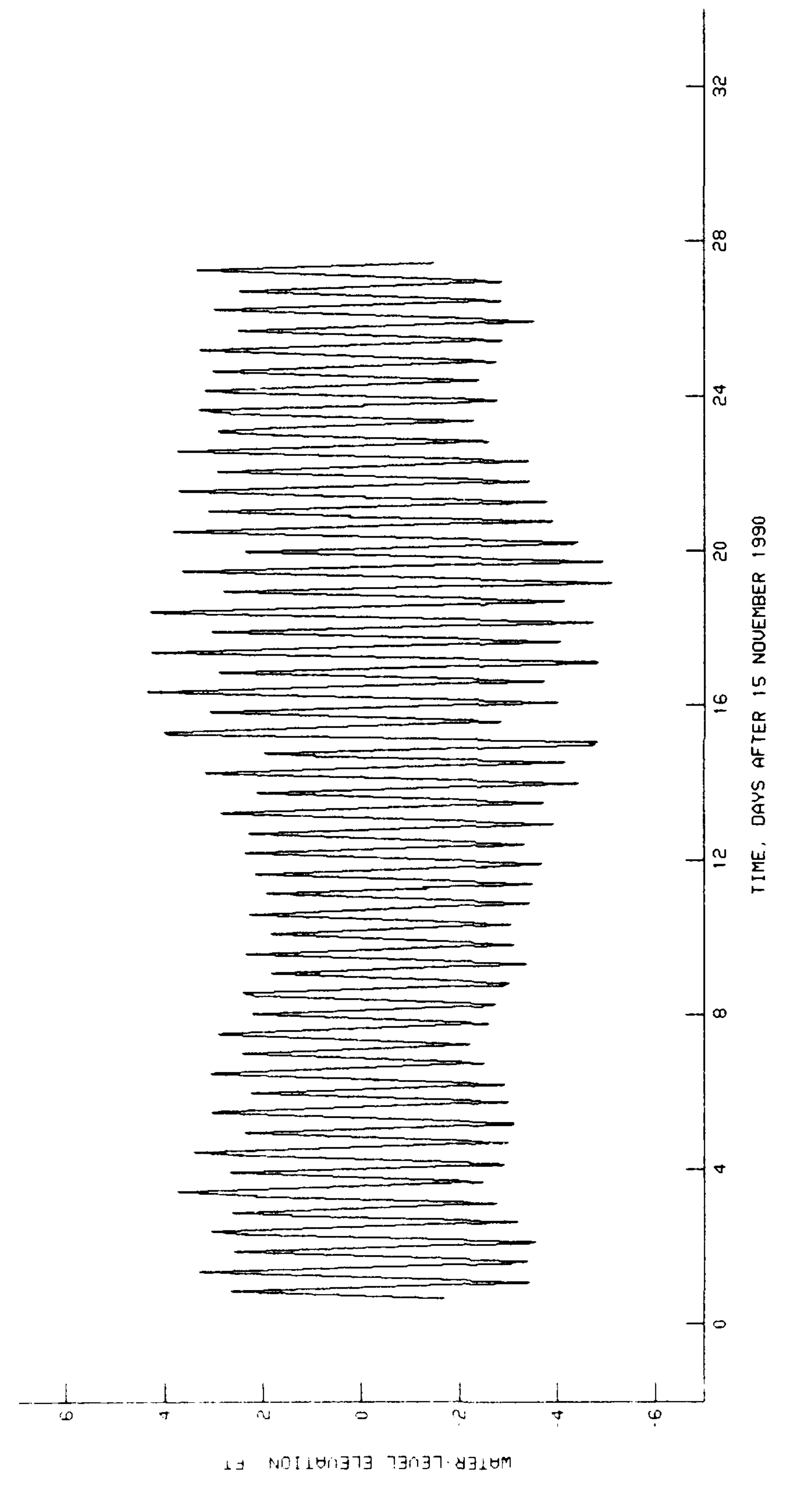

SALINITY, TLR-7
1 - 31 OCTOBER 1990
SALINITY, PPT
36
31
26
21
16
11
6
TIME, DAYS AFTER 1 OCTOBER 1990
0
4
8
12
16
20
24
28
32

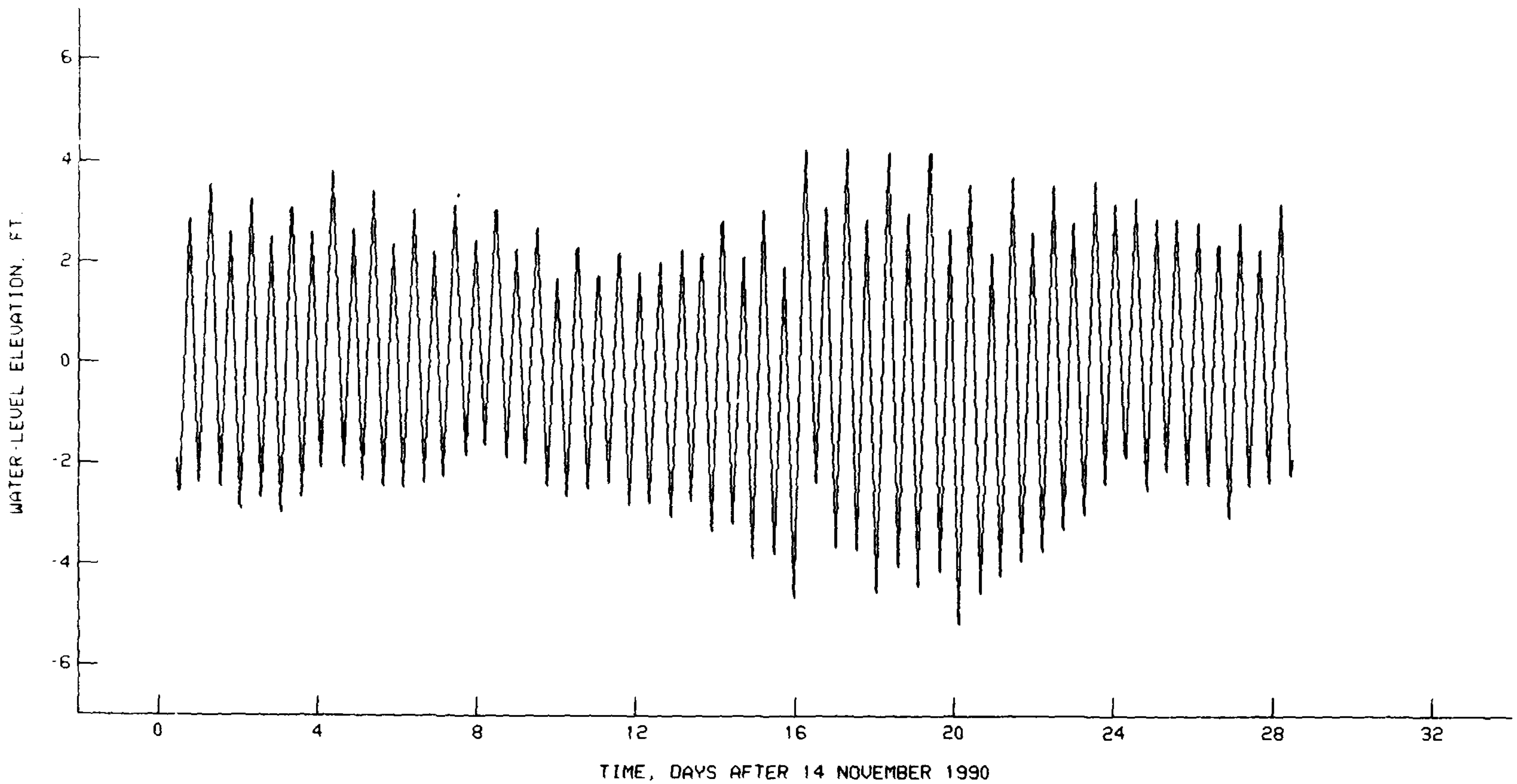
PLATE 24


WATER-LEVEL ELEVATION, TLR-4
15 NOVEMBER - 12 DECEMBER 1990
WATER-LEVEL ELEVATION, FT.
TIME, DAYS AFTER 15 NOVEMBER 1990
MEAN DATUM IS 4.32 FT MLW.
6
4
2
0
-2
-4
-6
0
4
8
12
16
20
24
28
32



MEAN DATUM IS 0.64 FT MLW.

WATER-LEVEL ELEVATION, TLR-5
15 NOVEMBER - 12 DECEMBER 1990



MEAN DATUM IS 3.94 FT MLW.

WATER-LEVEL ELEVATION, TLR-7
14 NOVEMBER - 12 DECEMBER 1990

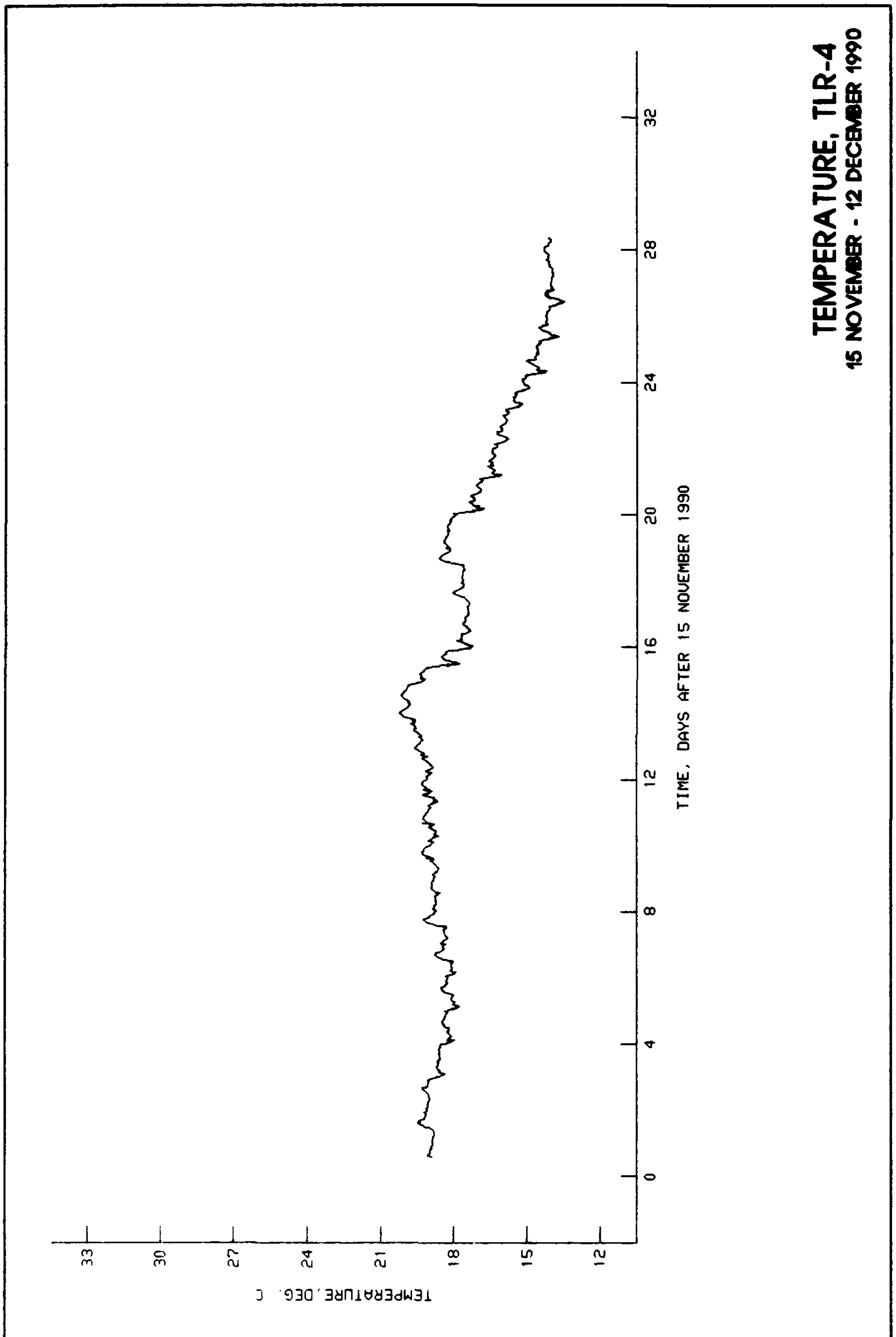
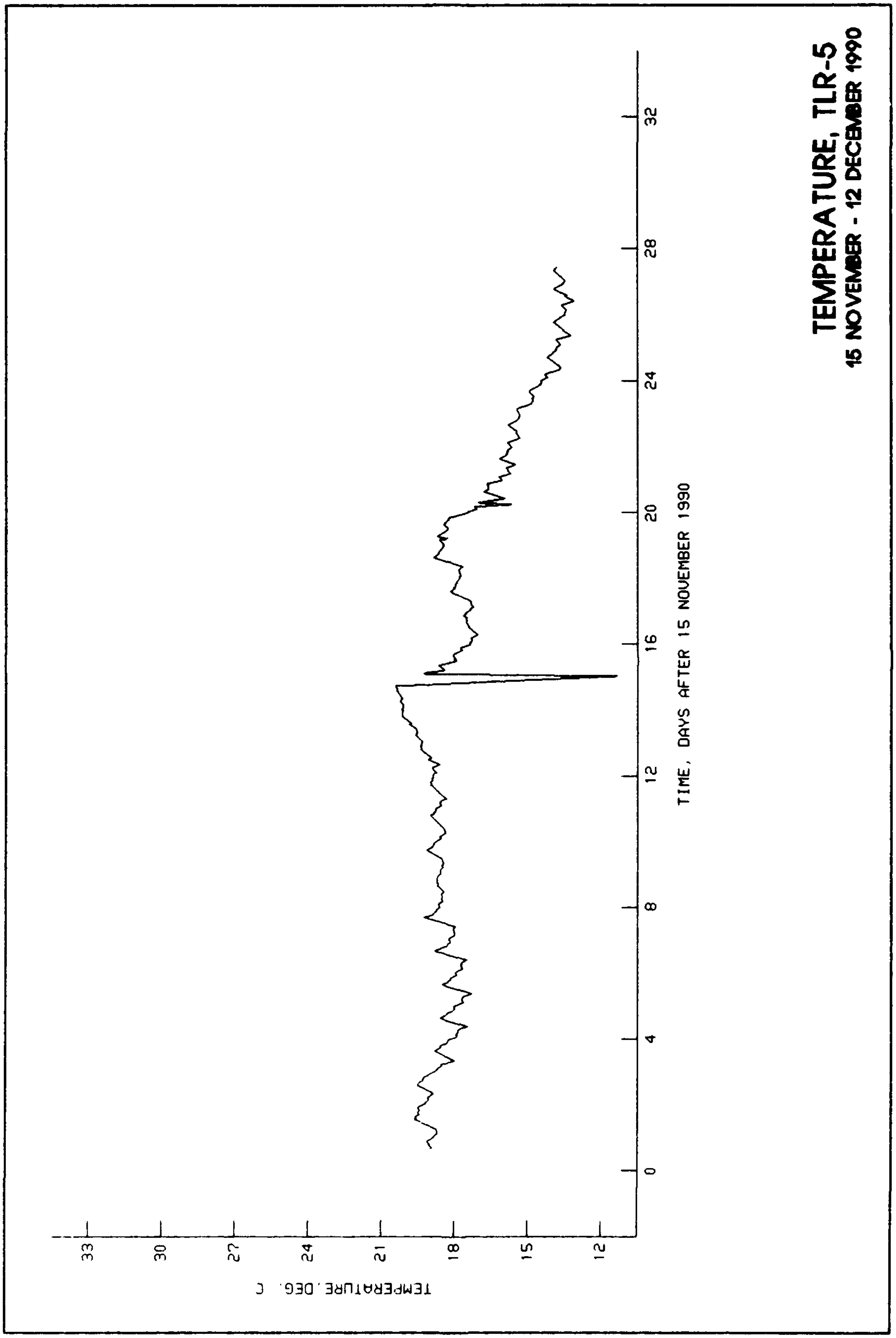

TEMPERATURE, TLR-4
15 NOVEMBER - 12 DECEMBER 1990
TEMPERATURE, DEG. C
12
15
18
21
24
27
30
33
TIME, DAYS AFTER 15 NOVEMBER 1990
0
4
8
12
16
20
24
28
32

PLATE 28



TEMPERATURE, TLR-5
15 NOVEMBER - 12 DECEMBER 1990

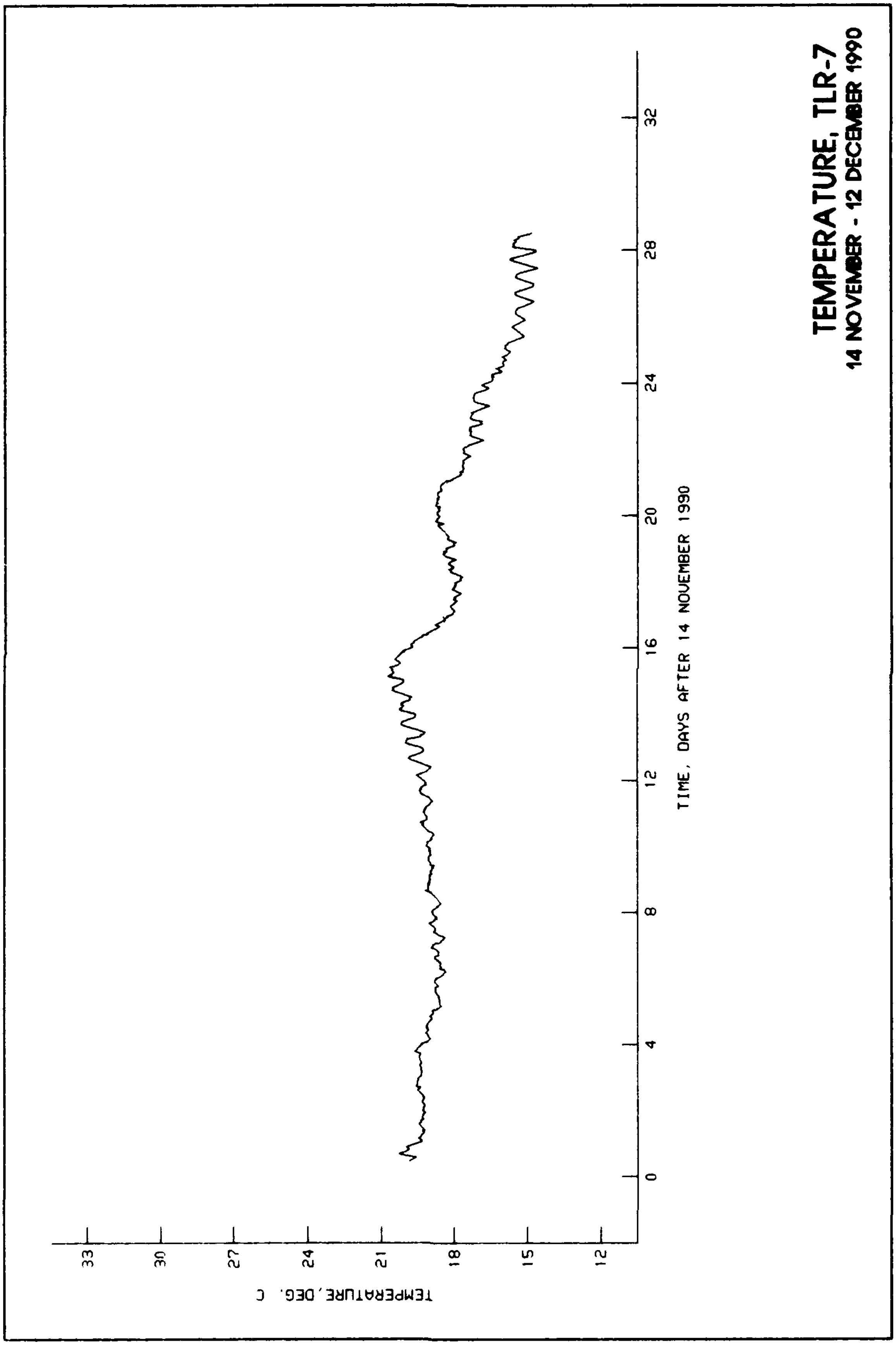
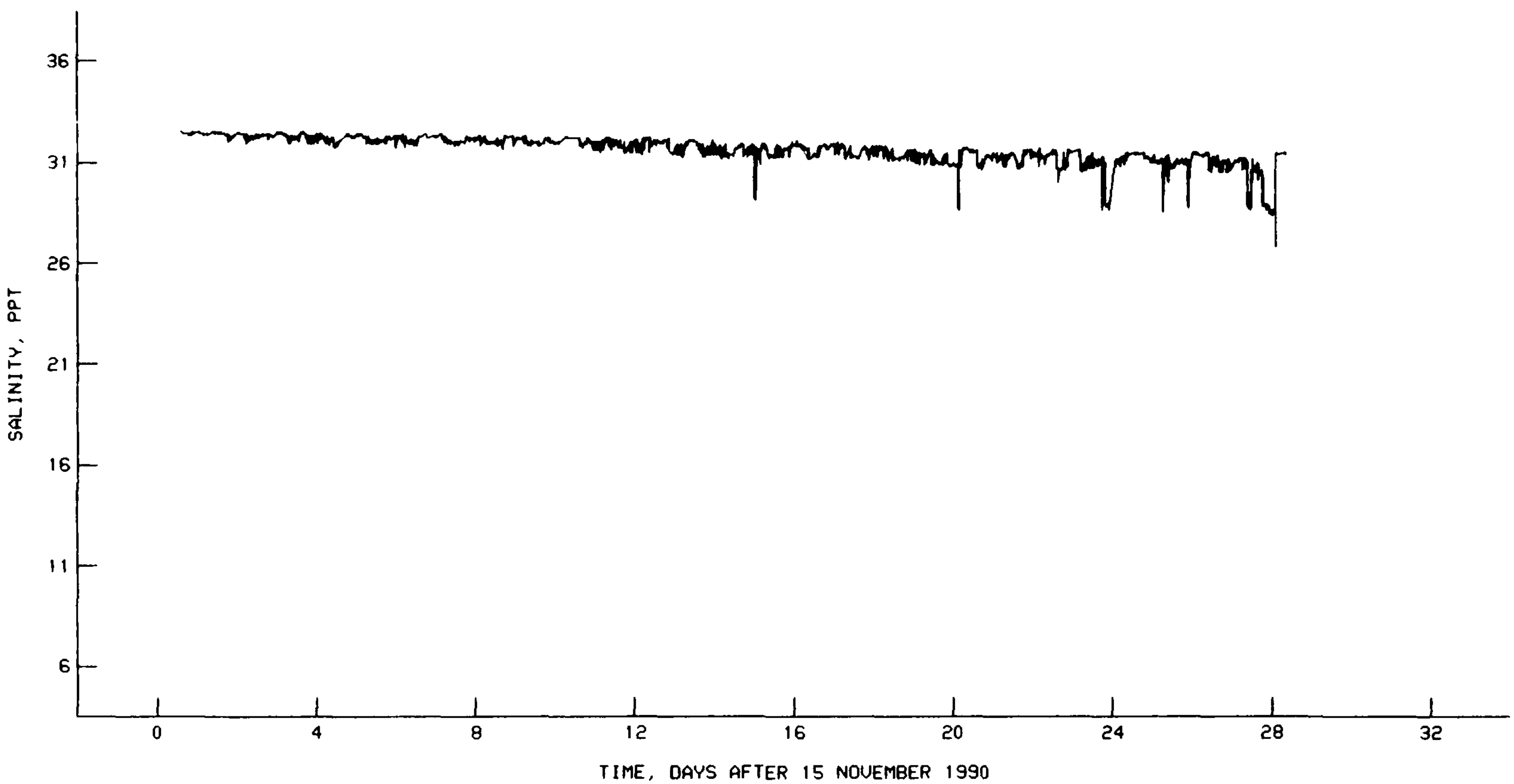

TEMPERATURE, TLR-7
14 NOVEMBER - 12 DECEMBER 1990
TIME, DAYS AFTER 14 NOVEMBER 1990
TEMPERATURE, DEG. C
0
4
8
12
16
20
24
28
32
12
15
18
21
24
27
30
33

PLATE 30



SALINITY, TLR-4
15 NOVEMBER - 12 DECEMBER 1990

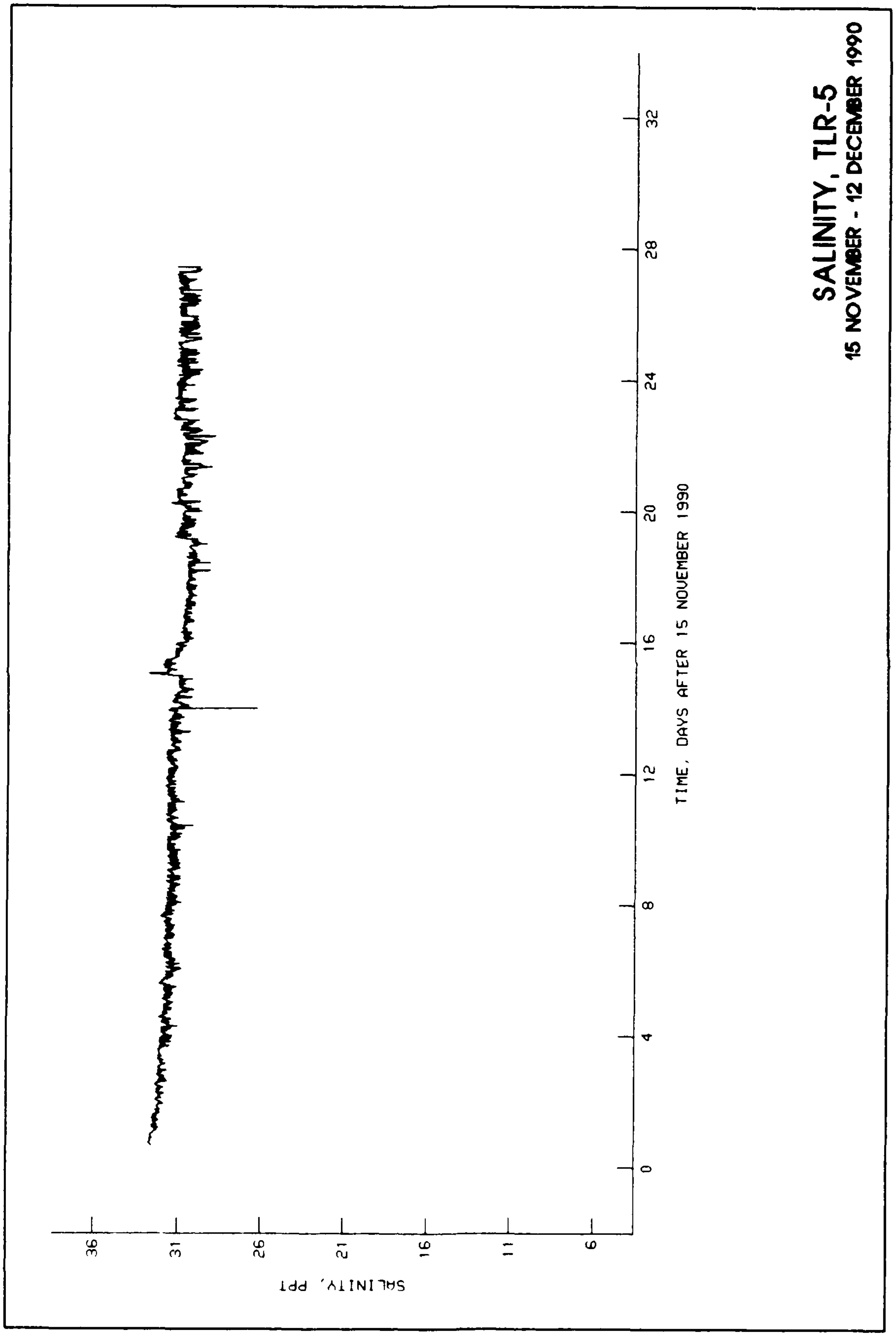
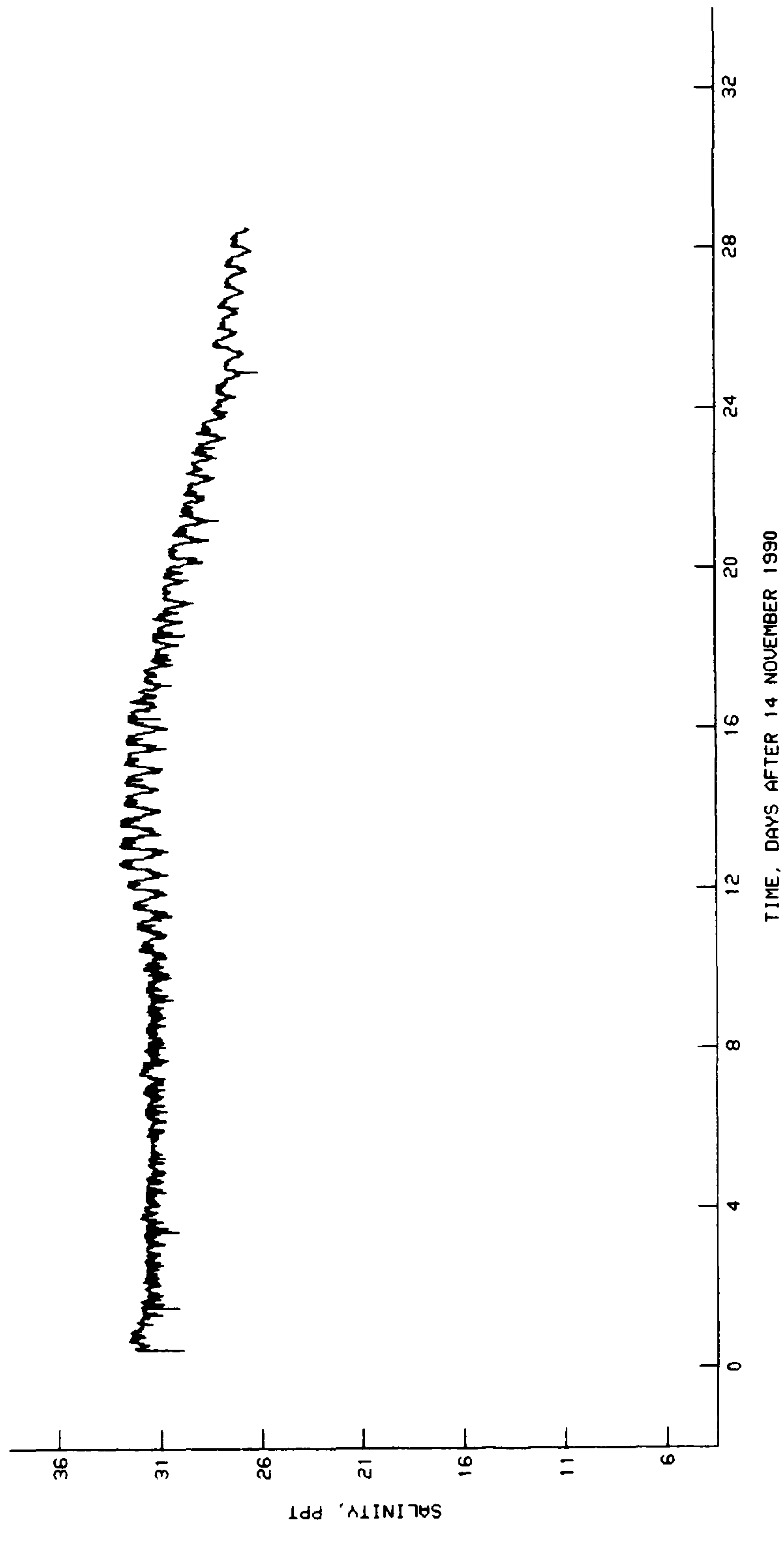
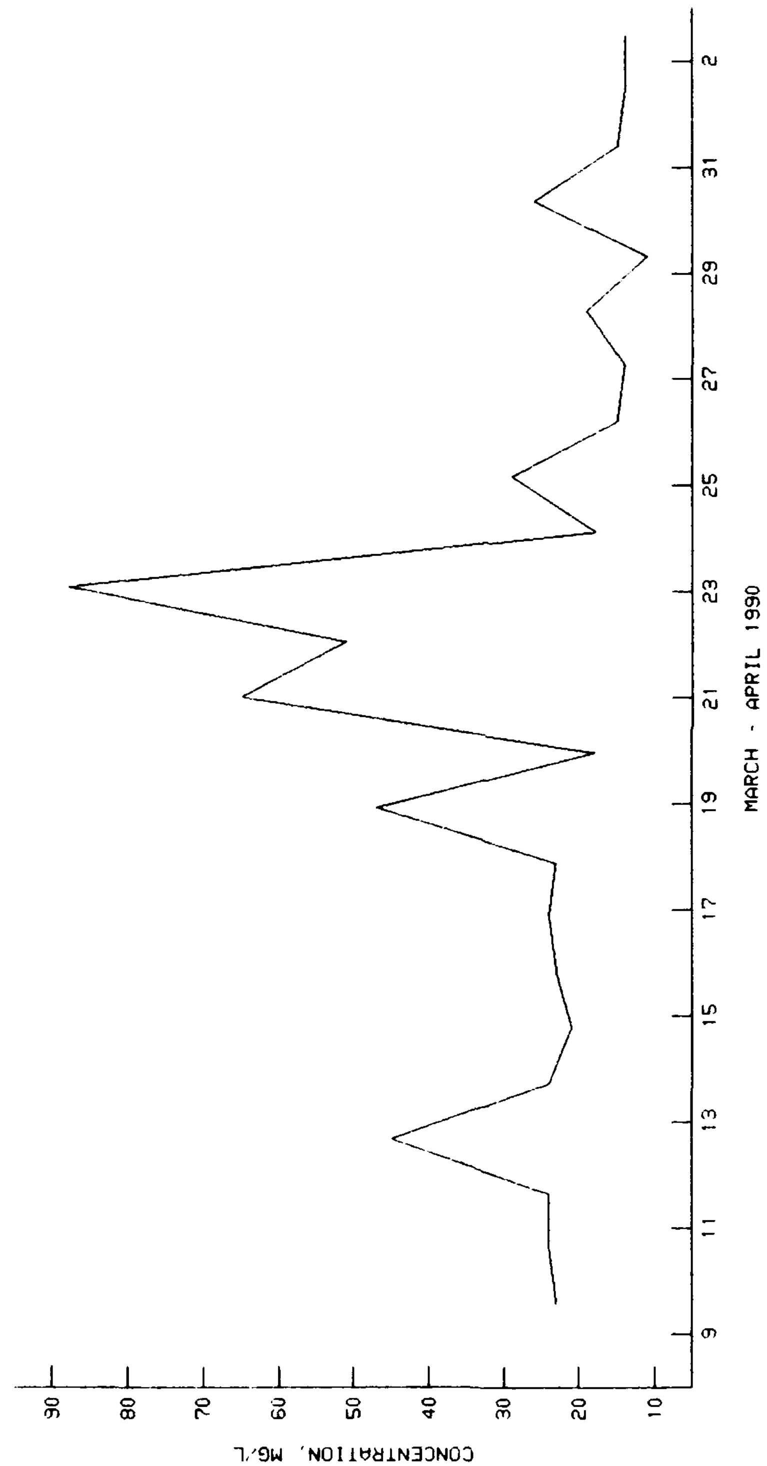

SALINITY, TLR-5
15 NOVEMBER - 12 DECEMBER 1990
SALINITY, PPT
36
31
26
21
16
11
6
TIME, DAYS AFTER 15 NOVEMBER 1990
0
4
8
12
16
20
24
28
32

PLATE 32

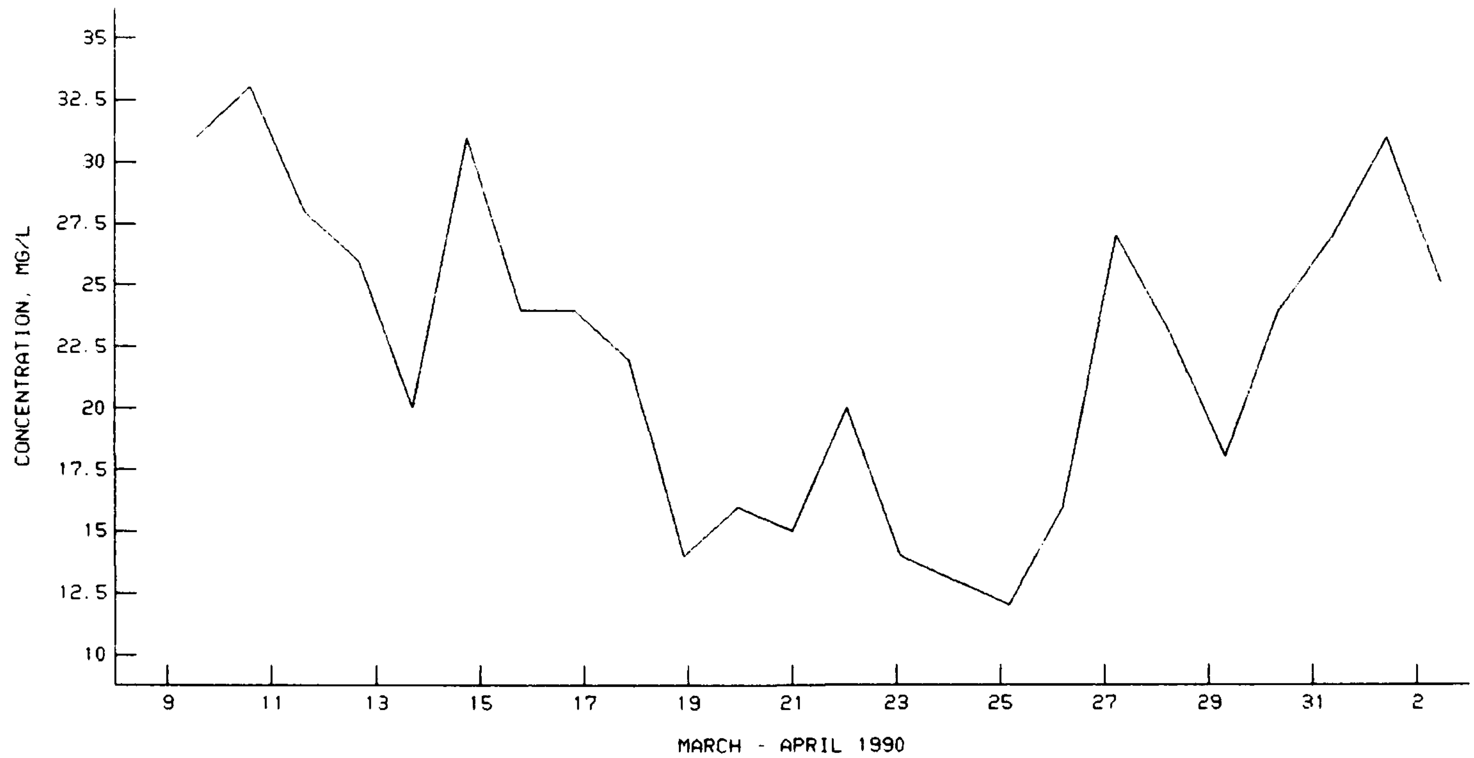


SALINITY, TLR-7
14 NOVEMBER - 12 DECEMBER 1990

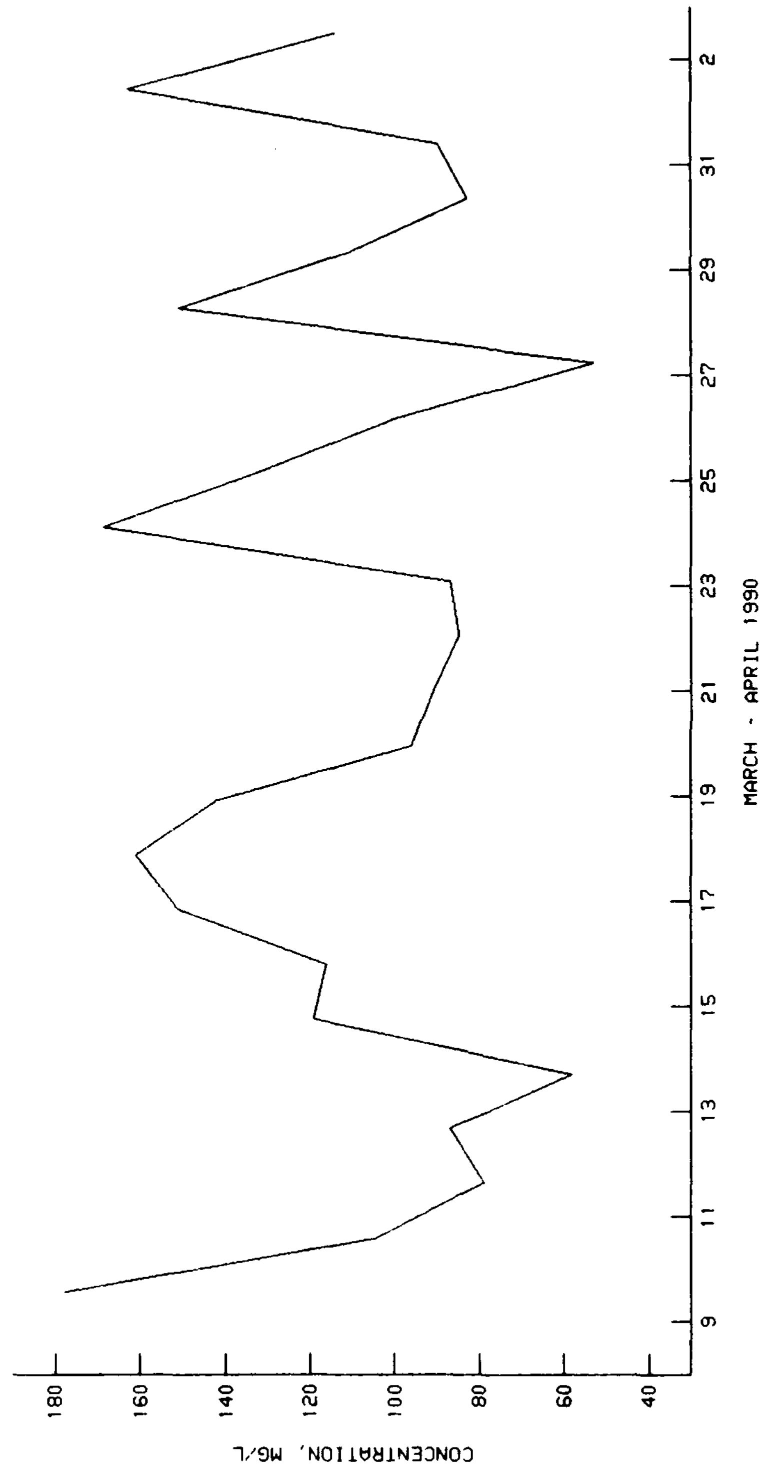


SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS4KB
9 MARCH - 2 APRIL 1990

PLATE 34



SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS5KB
9 MARCH - 2 APRIL 1990



SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS7KB
9 MARCH - 2 APRIL 1990

PLATE 36

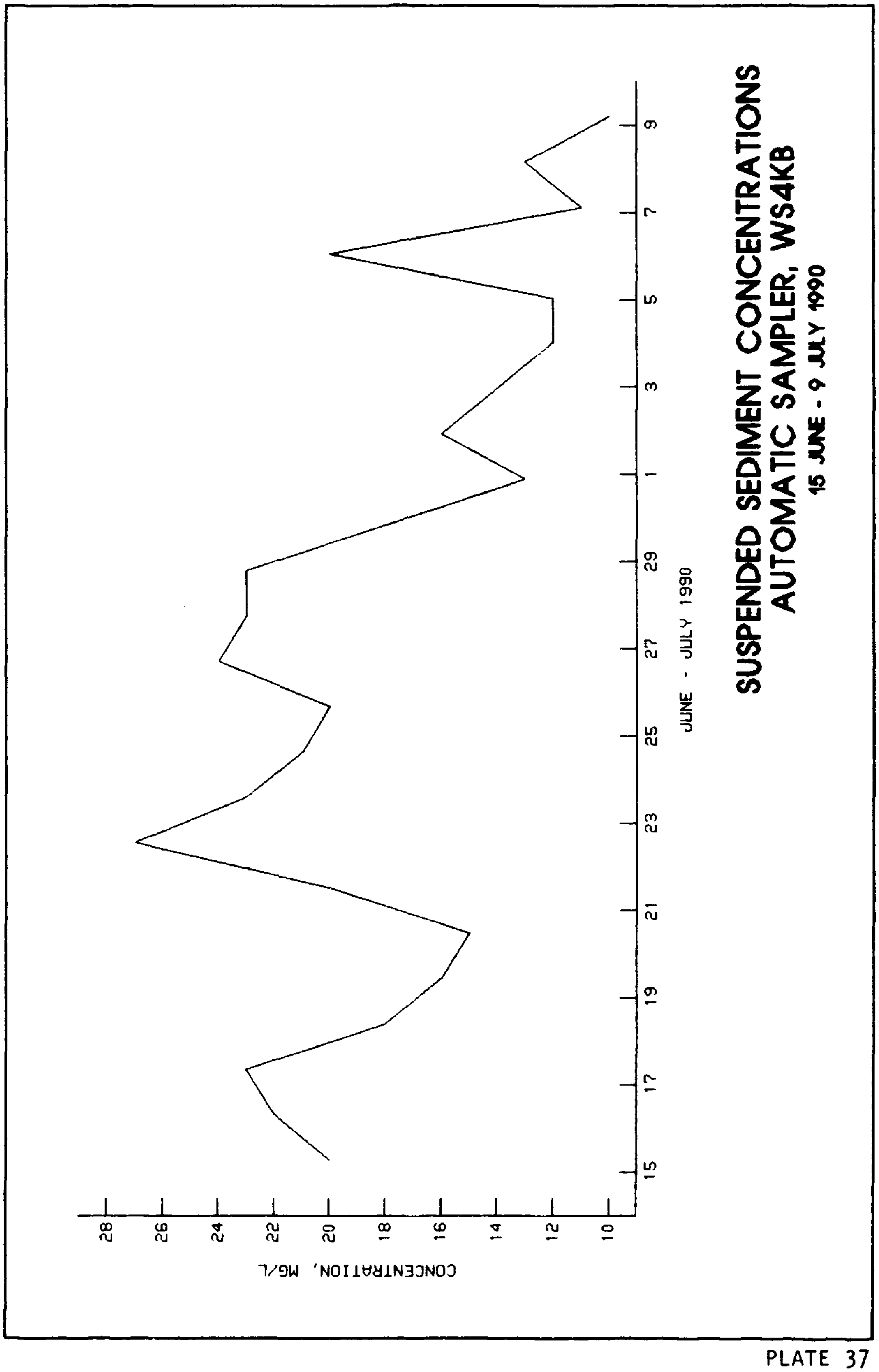
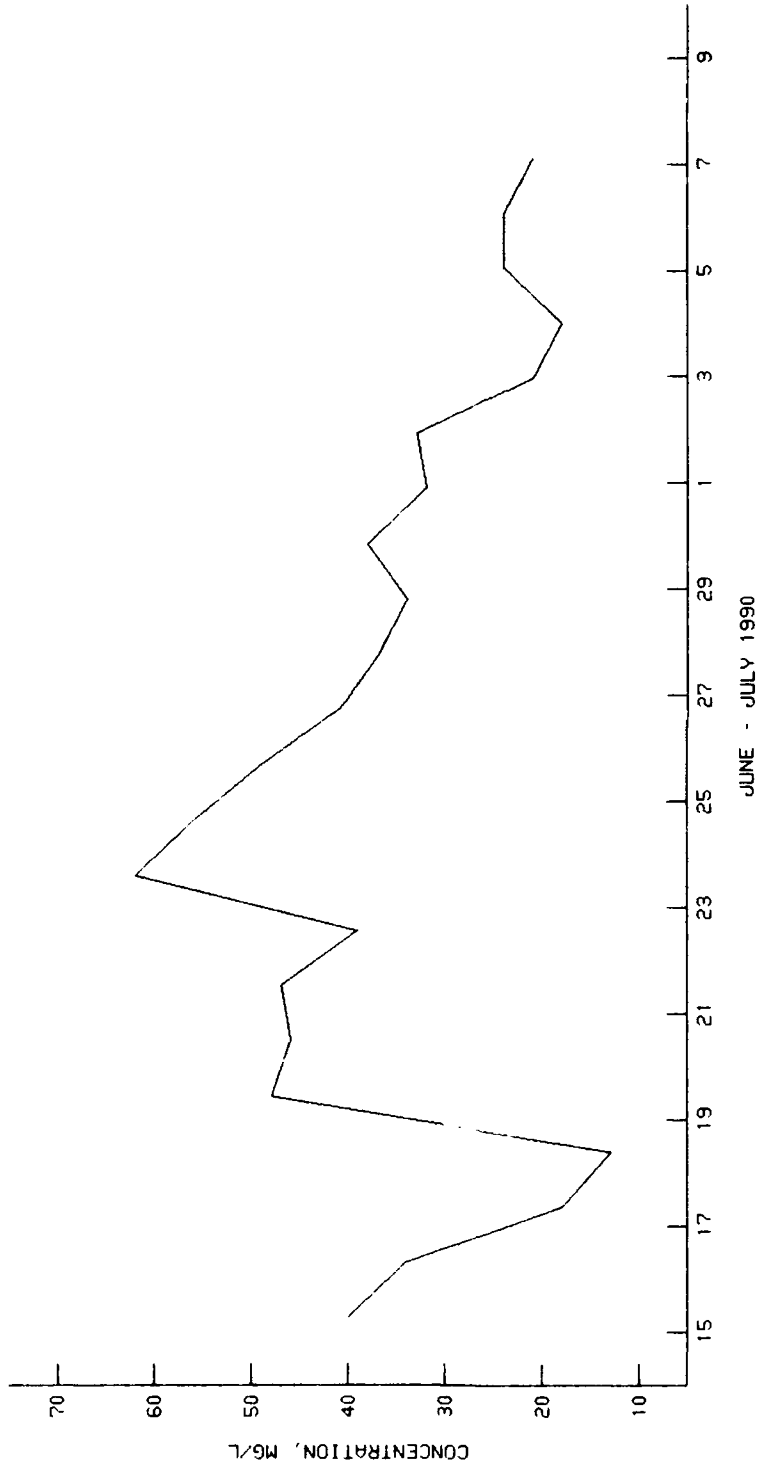
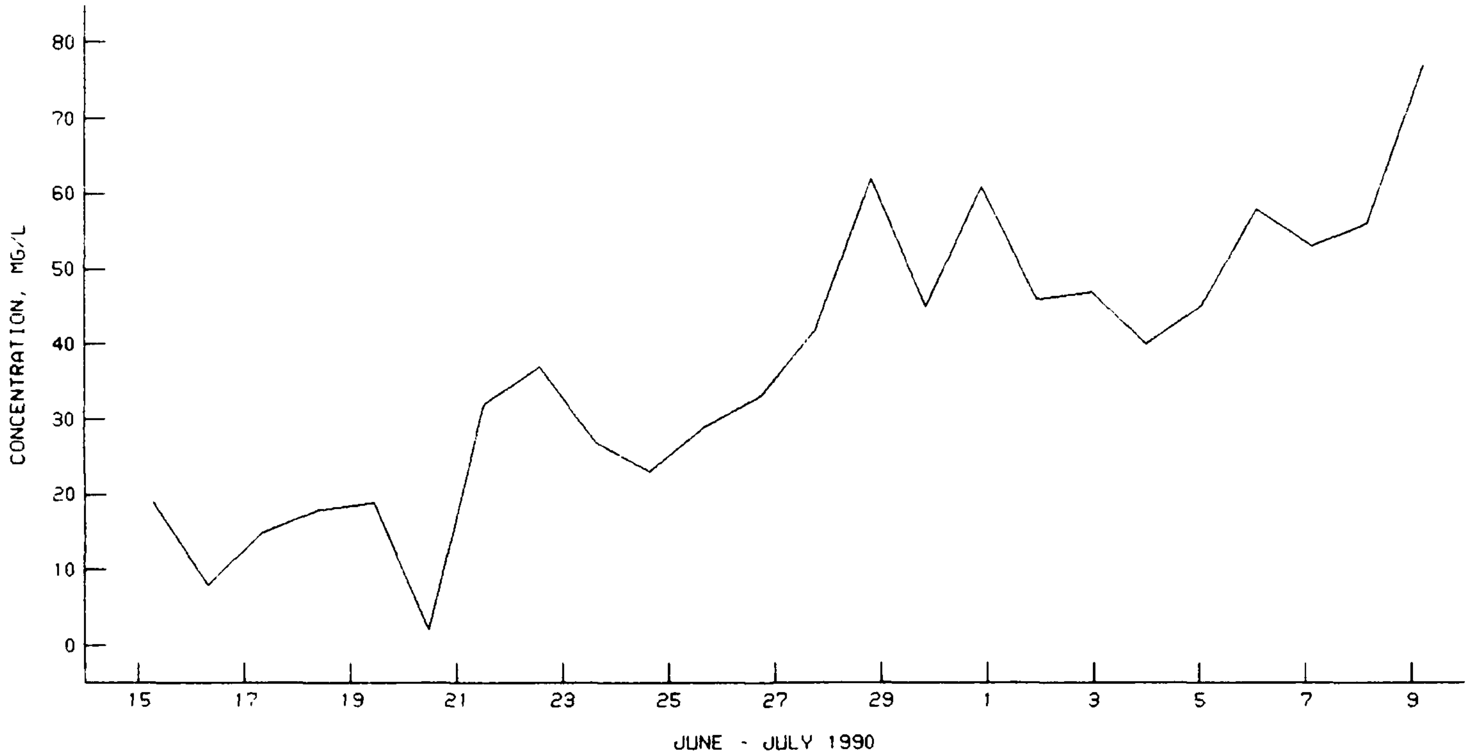

SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS4KB
15 JUNE - 9 JULY 1990
CONCENTRATION, MG/L
10
12
14
16
18
20
22
24
26
28
JUNE - JULY 1990
15
17
19
21
23
25
27
29
1
3
5
7
9

PLATE 37

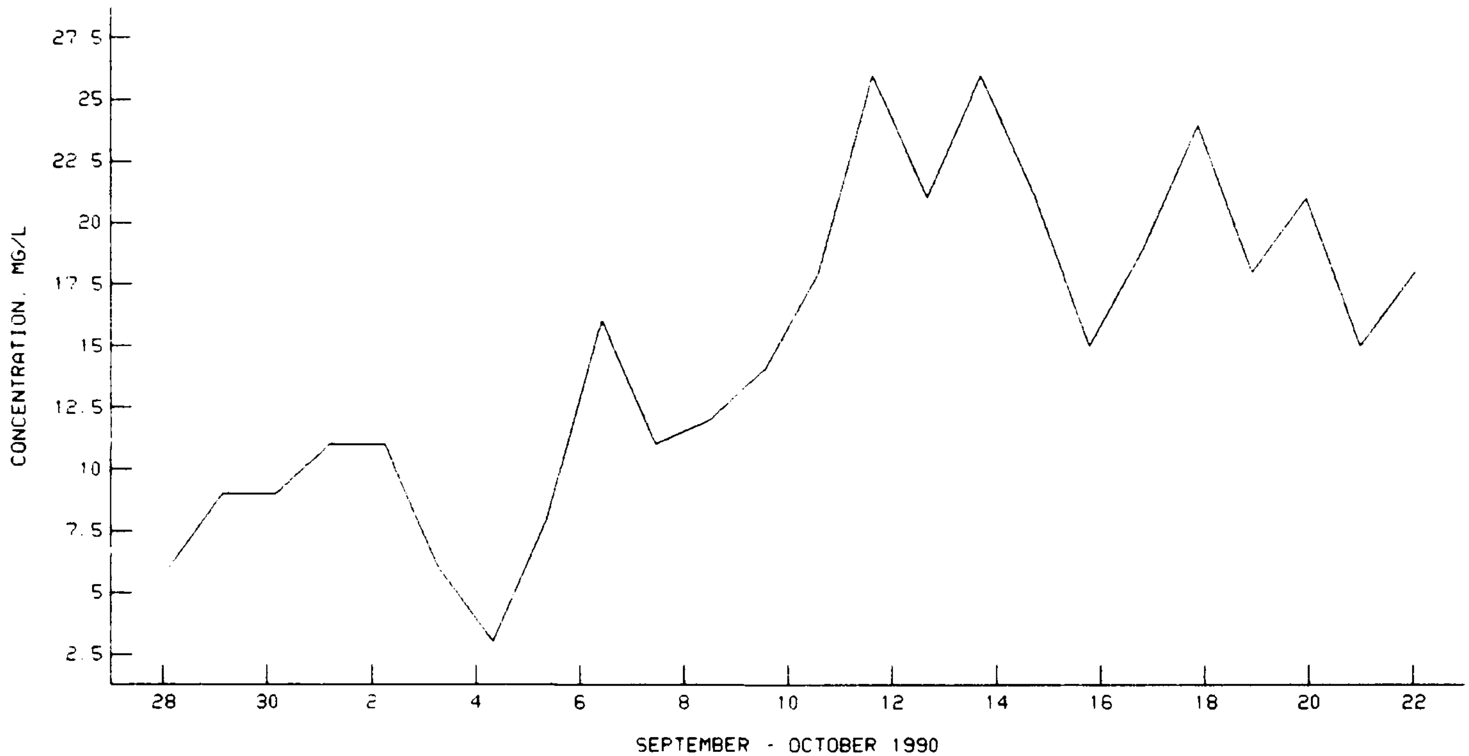


SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS5KB
15 JUNE - 9 JULY 1990

PLATE 38

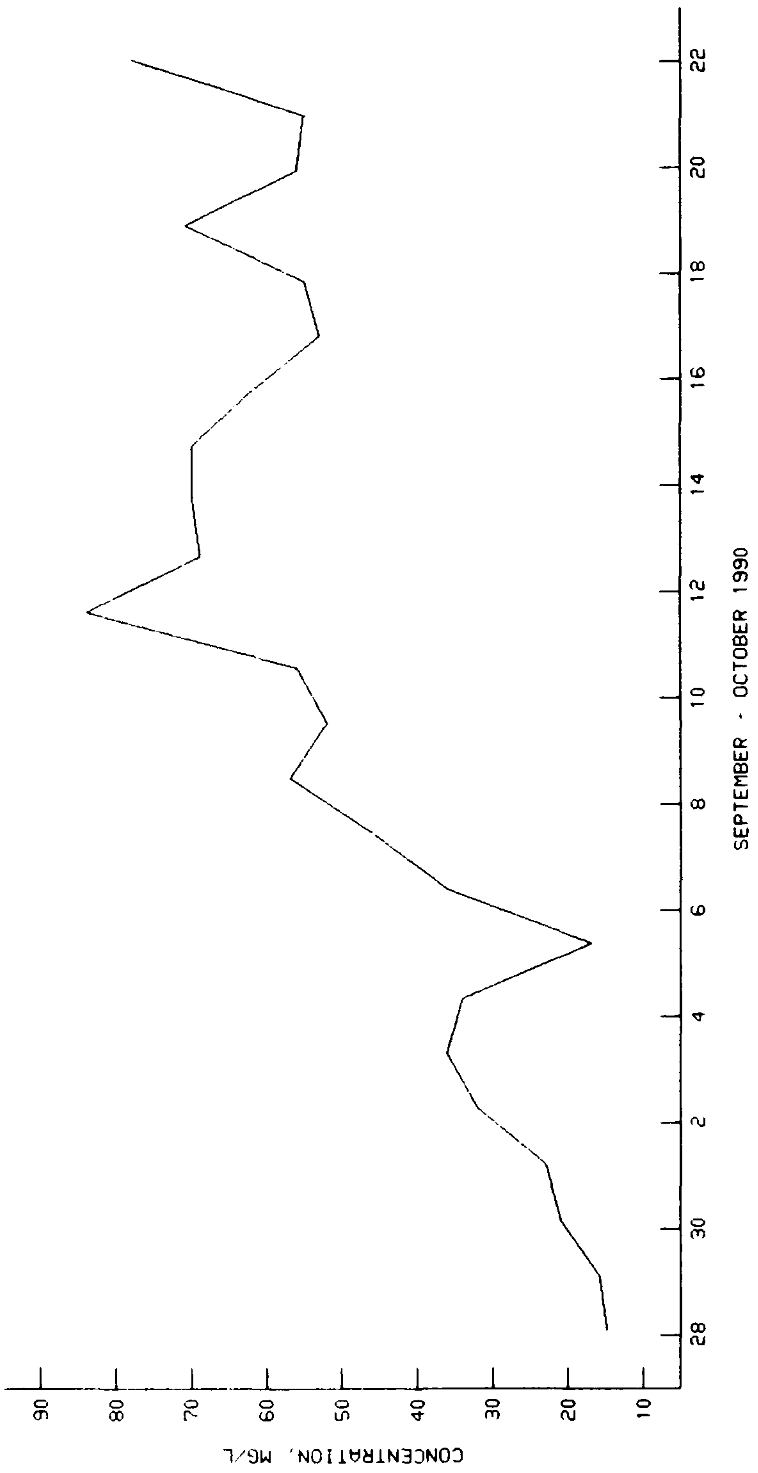


SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS7KB
15 JUNE - 9 JULY 1990

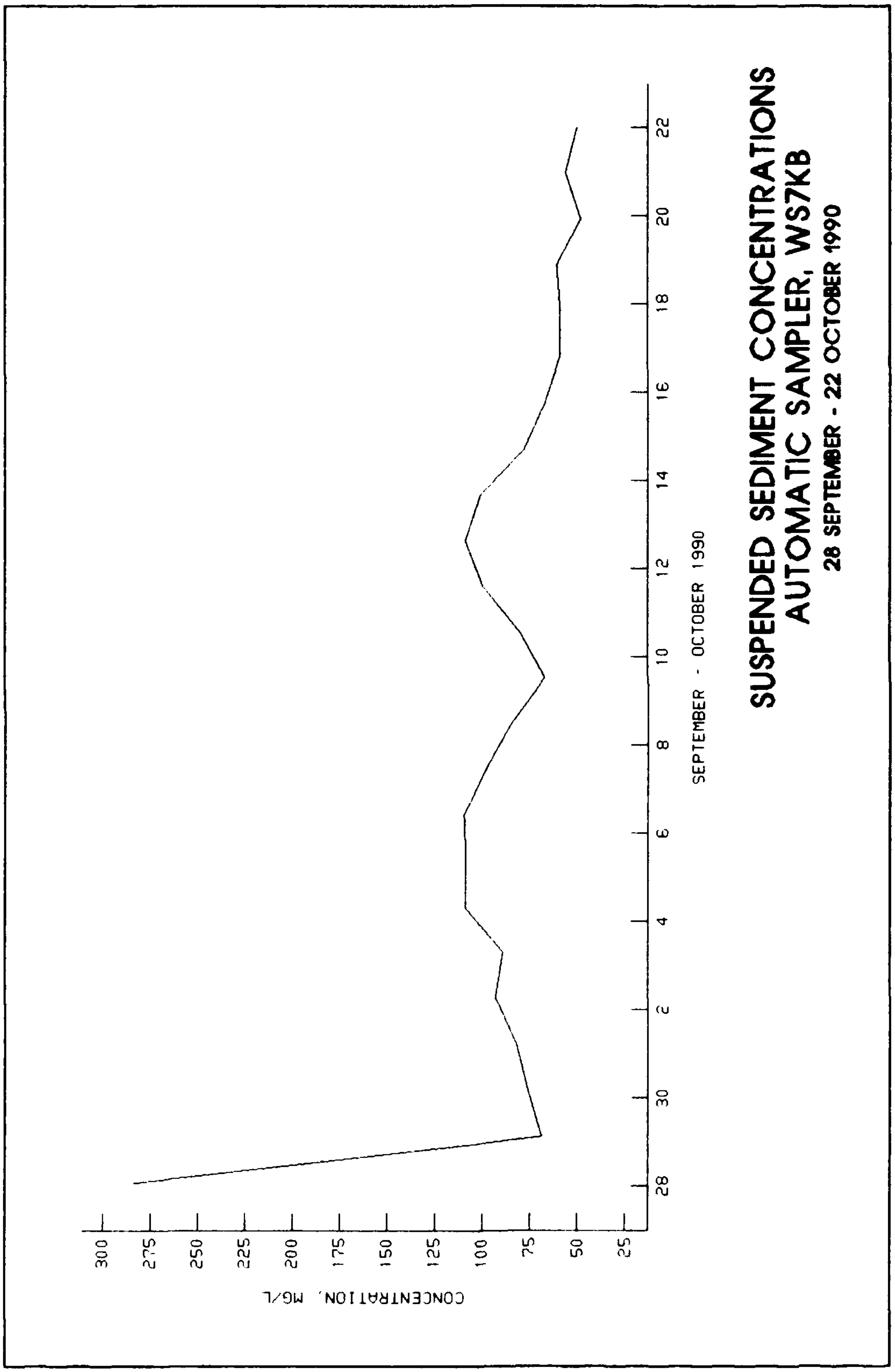


SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS4KB
28 SEPTEMBER - 22 OCTOBER 1990

PLATE 40



SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS5KB
28 SEPTEMBER - 22 OCTOBER 1990



SUSPENDED SEDIMENT CONCENTRATIONS
AUTOMATIC SAMPLER, WS7KB
28 SEPTEMBER - 22 OCTOBER 1990

PLATE 42